A COMPARATIVE STUDY OF THE LIFE-CYCLE OF CERTAIN PHYTOPHAGOUS SCARABAEID BEETLES

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WILLIAM PATRICK HAYES

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A COMPARATIVE STUDY OF THE HISTORY OF CERTAIN PHYTOPHAGOUS SCARABÆID BEETLES

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SUMMARY

This bulletin is an attempt to compare the life cycles of certain species of the subfamilies, Melolonthinæ, Rutelinæ, Dynastinæ, and Cetoniinæ of the coleopterous family Scarabæidæ. In all, 16 species are considered and the life cycles as observed at Manhattan, Kan., are compared with the life cycles of other members of the family. Each of the species, in so far as possible, has been considered in relation to its distribution, relative abundance at Manhattan, the attraction to lights, period of flight, food habits both in the adult and larval stages, the proportion of sexes, mating, oviposition, and the length of the various stages. From necessity, data on the various stages were condensed into tables in which the maximum, minimum, and average periods of development are stressed.

In the Melolonthinæ, 17 of the 25 species of *Phyllophaga* occurring at Manhattan have been reared. The data on seven of these have been published elsewhere and the remaining ten are discussed herein. Six of the seventeen species have not been studied heretofore and not much information is available for several others. Most of the species were found to have both a two-year and a three-year life cycle when reared under artificial conditions. Systematic collections from 1916 to 1922 indicate that the normal period is three years. Two species, *P. affabilis* and *P. longitarsa* apparently develop in one year, while *P. tristis* may require one or two years to complete growth.

Except for the work of Smyth on certain Porto Rican species of Melolonthinæ, there is no available literature on the length of the various larval instars. Herein are presented considerable data on the various stages as observed in the ten species.

Three species of the Rutelinæ, *Anomala innubia* representing the tribe Anomalini and *Pelidnota punctata* and *Cotalpa lanigera* representing the tribe Rutelini were under observation. It is apparent that the Anomalini have a one-year cycle as observed for *A. innubia*. In previous papers the writer has shown that *A. binotata* and *Strigoderma arboricola* have one-year periods of growth, and the Japanese beetle, *Popillia japonica*, is known to have a corresponding life history. In the tribe Rutelini, a longer period of growth is required. *Cotalpa lanigera* requires two and often three years and *Pelidnota punctata* develops in two years.

In the literature there are several life histories of the Dynastinæ reported, all of which have an approximate one-year life cycle. Herein it is shown that *Ligyrodes relictus* falls in the same category. The beetles appear in the spring, lay eggs, and the resulting larvæ complete their growth by fall and the beetles hibernate.

The writer has shown elsewhere that two other dynastinids, *Ligyrus gibbosus* and *Ochrosidia immaculata* develop in one year. Others of the subfamily known to require the same, or approximately the same time, are *Strategus titanus, Strategus quadrifovatus, Dyscinetus trachypygus, Dyscinetus barbatus,* and *Euetheola rugiceps.*

The subfamily Cetoniinæ in two cases, here discussed, were observed to develop in one year, *Euphoria fulgida* being shown to have a slightly different

life history than *E. sepulchralis* but requiring approximately the same period. In the literature it is found that *E. inda* and *Cotinus nitida* likewise have a one-year period of growth.

A general comparison of the four subfamilies shows that the life cycle in the Melolonthinæ is highly variable and may require one, two, three, and probably, in northern latitudes, four years to complete growth. The Rutelinæ in one tribe, Anomalini, need only one year, while the other tribe, Rutelini, must have at least two and sometimes three years to mature. In the Dynastinæ and the Cetoniinæ, the life cycle requires but one year.

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A COMPARATIVE STUDY OF THE HISTORY OF CERTAIN PHYTOPHAGOUS SCARABÆID BEETLES[1]

WILLIAM P. HAYES[2]

INTRODUCTION

The recent catalogue of North American Coleoptera by Leng (1920) recognizes, among others, four groups of the family Scarabæidæ as of subfamily rank which were formerly considered of tribal value. These subfamilies, the Melolonthinæ, Rutelinæ, Dynastinæ, and Cetoniinæ contain the most injurious, and therefore better known, species of the Scarabæidæ. Until recent years, very little has been known of the life cycle of these insects, most of our knowledge having been based on fragmentary work, accounts of which are scattered in the literature.

The reason for our lack of knowledge is due to a series of complicated factors. There are numerous genera, the species of which are quite readily recognized in the adult form, but in the larval stage are almost indistinguishable. To identify them it is necessary to rear the specimens, which often requires a long period of time. In a number of instances, especially in the Melolonthinæ, a prolonged life cycle covering from two to three years, and in northern latitudes even four years, makes rearing difficult. Most of the life cycle is spent underneath the surface of the soil and consequently rearing of the larvæ must be done under artificial conditions. Since the grubs of one subfamily can scarcely be separated from those of another, it is necessary to study representatives from all the subfamilies because of the variations in the length of life in the various groups. Not only do they differ within the groups, but in some subfamilies the length of life may vary in different localities, due perhaps to differences in climate and latitude, and again they may vary in the same locality. Many in-

ACKNOWLEDGMENTS.—The writer desires to acknowledge his indebtedness to Prof. J. W. McColloch of Kansas Agricultural Experiment Station who directed the investigations herein reported and gave valuable aid in the prosecution of the work, as well as furnishing some of the data, especially that of the species considered under the Cetoniinæ; to Prof. Glenn W. Herrick of New York State College of Agriculture for reading and criticizing the manuscript; and to Prof. J. J. Davis of Purdue University and Mr. Warren Knaus of McPherson, Kan., for the determination of specimens.

1. Contribution No. 324 from the Department of Entomology. This bulletin embodies the results of some of the investigations undertaken by the author in the prosecution of Project No. 100 of the Kansas Agricultural Experiment Station.

2. This bulletin was also presented in August, 1923, by the author as a graduate thesis to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

stances of the variation in the same region are to be found, especially in the genus *Phyllophaga* in which one-, two-, or three-year cycles occur with specimens reared under identical conditions.

This bulletin is intended as a further report of the studies of Kansas Scarabæidæ, some of the results of which have already been published. (Hayes, 1917, 1918, 1919, 1920, 1921, 1922.) These studies include among the Melolonthinæ the species of *Phyllophaga* previously reported; viz., *futilis* LeC., *rubiginosa* LeC., *vehemens* Horn, *crassissima* Blanch., *rugosa* Mels., *implicata* Horn, *submucida* LeC., and *lanceolata* Say, to which are added *bipartita* Horn, *longitarsa* Say, *corrosa* LeC., *hirticula* Knoch, var., *comosa* Davis, *affabilis* Horn, *crenulata* Froel., *fusca* Froel., *vehemens* Horn, *prætermissa* Horn, and *tristis* Fab.

Additional species of the Rutelinæ here treated are *Anomala innubia* Fab., *Pelidnota punctata* Linn., and *Cotalpa lanigera* Linn. Only *Ligyrodes relictus* Say among the Dynastinæ is discussed, and two species of *Euphoria, E. fulgida* and *E. sepulchralis* represent the Cetoniinæ.

ECONOMIC IMPORTANCE

The larvæ of the subfamilies here considered are recognized in many parts of the world as pests of planted crops and are almost universally known as "white grubs." One of the most famous members of the group is the European "hanneton" *Melolontha melolontha* which has been known for over a century as a destructive enemy of the roots of crops. It belongs to the subfamily Melolonthinæ to which our common American species of May Beetles or June Bugs (*Phyllophaga*) are assigned. Certain species of *Phyllophaga,* both adults and larvæ, are perhaps the most destructive members of the family in North America and their injury is too well known to require extended discussion.

In Kansas, the greatest loss from white grubs occurs in the southern part of the state where the larvæ of *P. lanceolata* attack the roots of wheat and often destroy thousands of acres in a single season. Considering the state as a whole, most of the principal crops as well as native prairie pastures, meadows, and lawns have suffered injury. In some localities gardens suffer. Potatoes especially have paid a heavy toll in the last few years. Strawberry beds have been the object of regular attacks and ornamentals of all kinds, particularly those recently set out, have been seriously damaged. Many of the lawns in the state have been killed by the grubs and serious loss has occurred in the bluegrass pastures

of eastern Kansas. Alfalfa which, according to Davis (1918), is usually considered free from injury, has been found damaged in a number of localities. In the case of this crop, the grub enters the tap root an inch or two below the surface of the soil, excavates a cavity and burrows upward and downward in much the same manner as some of the root-boring insects.

Among the Rutelinæ, two species here considered, *Pelidnota punctata* and *Cotalpa lanigera* are notably injurious in the United States. The damage caused by the "Spotted grapeleaf beetle," *Pelidnota punctata* Linn., to the foliage of grapes during some years attracts considerable attention, but the larvæ, living in rotten wood, such as logs and old stumps, can be regarded as beneficial because their activities in these situations hasten decay. The "Goldsmith beetle," *Cotalpa lanigera* Linn., has been reported by Davis (1916), as ranking next in importance to the species of *Phyllophaga.* He says that the grubs in Michigan are destructive to raspberry bushes, strawberries, corn, and grass. The other species of Rutelinæ here treated, *Anomala innubia* Fab., is not of so much economic importance but at times becomes numerous and the beetles do some damage to the kernels of growing wheat, which they attack while "in the milk." The grubs feed on the roots of various plants. An important introduced member of this subfamily is the "Japanese Beetle," *Popillia japonica* Newm.

The representative of the Dynastinæ dealt with herein, *Ligyrodes relictus* Say, is not known to be a crop pest, but a near relative, *Ligyrus gibbosus* DeGeer, is an important enemy of carrots and domesticated sunflower crops. This species, known as the "carrot beetle" has been shown to have a one-year life-cycle.

The best known American species of the Cetoniinæ are the "Bumble flower beetle," *Euphoria inda* Linn., and the "Green June beetle" also called the "fig eater," *Cotinis* (= *Allorhina*) *nitida* Linn. The Bumble flower beetle is a somewhat general feeder, being found upon flowers, eating the pollen, and upon corn stalks where it feeds on the green cob by sucking the juices. It also occurs on peaches, grapes and apples, and occasionally its injury becomes serious. The larva is not known to cause damage. The Green June beetle, on the other hand, is a pest in the grub stage, feeding upon the roots of grasses and often doing immense damage to lawns and golf courses. (Chittenden and Fink, 1922.) The two species of Euphoria here considered, *E. sepulchralis* and *E. fulgida,* are neither of great importance economically. They feed in the adult stage on

the pollen and nectar of flowers and Chittenden and Fink (loc. cit.) report the beetles of *E. sepulchralis* feeding on the tips of ears of corn and making way for further injury by the Green June beetle, *Cotinis nitida.*

HISTORICAL CONSIDERATIONS

It is not the purpose here to give a detailed account of the many interesting historical facts connected with the family Scarabæidæ, for Burmeister (1842) has done this admirably. Instead, it is planned to mention but a few of the important details involving changes in the nomenclature.

The origin of the word Scarabæus is clouded in uncertainty. Various authors attribute it to the Latin and others to the Greek. According to MacLeay (1819), it was originally used by the Romans to designate the Coleoptera and as such is used by Pliny who also used it in a definite description of the sacred beetles of Egypt, and ultimately it became restricted to them by earlier naturalists. Linnæus (1758) was the first who can be considered as applying the term properly. He included all that we now know as Lamellicorns and as such was more inclusive than what we now regard as the family Scarabæidæ.

The first splitting of the group as defined by Linnæus occurred when Scopoli (1763) separated the genus *Lucanus* from *Scarabœus.* Fabricius, Olivier, and others soon followed with many new genera and ultimately the two groups as represented by *Lucanus* and *Scarabœus* became known as the Lamellicornia, a term which was first used by either Lamark (1817) or Latreille (1817). According to Burmeister (loc. cit.) it is not known which of the two was the originator of the term, but it is more generally attributed to Latreille, whose work became known to entomologists in general, and to him also is credited the origin of our modern conception of the family group. From him we have derived the family names *Lucanides* and *Scarabœides,* while the modern termination *idæ* was for the first time generalized in entomology by MacLeay in 1819. As now recognized, the American representatives of the family Scarabæidæ comprise 14 subfamilies (Leng. 1920), only four of which are here considered. The remainder are not recognized as plant feeders and were, therefore, not considered in this study.

REVIEW OF LITERATURE[3]

Previous to 1916, our knowledge of the life cycle of the American species of Phyllophaga was confined to the contributions of Chittenden (1899) who reared a single individual of *P. fervida* (*arcuata*), and to those of Davis (1913) who reported a two-year life cycle for *P. tristis*. In 1916, Davis reported the length of life of 18 species of the genus, but did not discuss the length of the various stages. This work is of great importance to our knowledge of the group and gave to the writer his inspiration to make a further study of a similar nature. Smyth (1917) reported the results of life history studies of certain Porto Rican species of Phyllophaga and one other Melolonthid, *Phytalis insularis* Smith, in which our first account is to be had of the length of the various instars.

As a part of the present study, the writer has reported on representatives of three of the subfamilies here considered. Among the Melolonthinæ the genus *Phyllophaga* only has been studied sufficiently to report results (Hayes, 1919 and 1920). Seven species, *futilis, rubiginosa, vehemens, crassissima, rugosa, implicata,* and *submucida* were found to have two- and three-year life cycles. One species only, *vehemens,* was observed to have a three-year period of development, although, as pointed out later in this paper, it may have a two-year cycle also. Another species, *P. lanceolata,* with quite different habits, was found to have a two-year cycle. Among the Rutelinæ, *Anomala binotata* and *Strigoderma arboricola,* were found (Hayes, 1918 and 1921) to have a one-year cycle. In the Dynastinæ likewise a one-year period for *Ochrosidia immaculata* (nec villosa) and *Ligyrus gibbosus* DeGeer (Hayes, 1917) was observed.

DATA AND DISCUSSION

The present study which was begun in 1916 was for the purpose of ascertaining the life cycle of as many members as possible of this family. The food plant relations, periods of flight, and other ecological factors were also observed. The specimens used for study were collected and reared in Riley county, Kan., near the vicinity of the city of Manhattan. Collections have been made throughout nearly the whole period of flight of the species studied. A total of

3. A family of beetles as well known as the Scarabæidæ naturally would have a great deal written concerning it. A large bibliography of the species reported herein has been prepared. Many of the references are short discussions of injury by the species or methods of controlling them and represent no original work. Because of the limitations of space, it has been deemed advisable to omit from the appended bibliography references of such a nature. Citation has been made to the more important.

91,490 adult Phyllophaga and several thousand specimens of the other genera were collected and studied. Large numbers were handled in rearing cages in order to bring to maturity the comparatively few which survive the long period of development under artificial conditions. During the course of the work, especially with some of the more common species, it was not uncommon to start from 1,000 to 2,000 individual cages of newly hatched grubs with the ultimate result of having less than a dozen mature.

Beside the data gathered from original collections, recourse has been had to the literature, especially for distributional records. The collections of the Kansas State Agricultural College, University of Kansas, and the private collection of Mr. Warren Knaus of McPherson, Kan., have been seen and studied, and more recently the writer has had access to the collections of Cornell University.

Methods of Rearing

On account of their subterranean habits and long period of development, white grubs are difficult to rear to the adult stage. The difficulty arises not only from their prolonged life cycle, but also because of the many parasitic fungi and other diseases attacking the grubs while being reared under artificial conditions. In order to be sure of having some specimens mature, it was necessary to handle large numbers of eggs and larvæ, and to study molting it was necessary to keep them isolated. Davis (1915) and Smyth (1917) have devised methods of rearing white grubs and May beetles and suggestions of these two writers were followed in this work. These methods with some others are here briefly summarized.

To procure eggs it was necessary only to confine the beetles over a few inches of damp, well-packed soil. Hence, any sort of cage to confine the beetles was used, but in the main most of them were in one-gallon tins, the tops of which were perforated and were half filled with moist earth. The leaves of various trees were frequently supplied for food by merely placing them on the surface of the soil. The earth was sifted or carefully gone over for eggs every other day. It was found that disturbing the soil every day produced a tendency for the beetles to lay fewer eggs. The eggs were transferred to individual cavities in closely packed, dampened soil in one- or two-ounce tin salve boxes, where they were kept until hatched. From 25 to 50 eggs can be cared for in each box in this manner. Upon hatching, each grub was placed in a one-ounce salve box where it was kept until it matured or died. These salve boxes, at times numbering over 5,000, were kept in the rearing cave described by Mc-

Colloch (1917) in which there was a nearly constant temperature, and thus the grubs were not subjected to the daily fluctuations of temperature in the outdoor insectary. The grubs were examined, with the aid of student assistants, twice a week during the warmer parts of the year, once a week in spring and autumn, and once a month during the winter months, and at each examination the soil was changed and new food (generally a few grains of wheat, which soon germinated) was added, except in the winter when the food was omitted. When a grub reached the prepupal stage, the soil in the box was tightly packed and the grub placed in a depression to stimulate a pupal cell. These prepupæ were then isolated from the others and examined daily to obtain the dates of pupation and maturity.

All of the species herein discussed were thus handled with the exception of *Pelidnota punctata* whose habit of living in rotten logs during the larval stage made some changes in the above procedure necessary. This species, the most difficult of any to rear, failed to thrive in individual salve boxes in which rotting pieces of wood were substituted for the grains of wheat. Only one specimen was thus reared. Other specimens, however, were reared in decaying wood placed in one-gallon tins and left undisturbed. This method means that the molting periods must be overlooked.

One other slight deviation from the general method of rearing was necessary in the case of *Ligyrodes relictus* and the *Euphoria* grubs whose larval stage is passed in manure and other decaying vegetable matter. In these cages, instead of feeding wheat grains to the grubs, which, however, they will eat, the soil in which they were placed was made more to their liking by adding to it an equal amount of dried manure.

The eminent Coleopterist, Horn, wrote (1887): "There is probably no genus of the Scarabæidæ in our fauna about which so little is known by the numerous collectors in our country as *Lachnosterna*. This, too, in face of the fact that the species are for the most part of large size and abundant whenever found. Unfortunately there are no striking differences between the species which arrest the first glance . . . Lachnosterna is certainly one of the most difficult genera in our fauna and the correct determination of the species has been rendered uncertain by the large proportion described from uniques."

Facing such a contingency at the beginning of a study of the family Scarabæidæ with the species of its most important genus

difficult to identify, it became necessary to seek aid in the recognition of specimens. Mr. J. J. Davis, entomologist of the Indiana Agricultural Experiment Station, who at that time was engaged in a study of the group for the United States Department of Agriculture, Bureau of Entomology, gladly furnished the writer with a long series of *Phyllophaga* correctly determined from their extruded genitalia. He extended further aid by determining many specimens, especially of the rarer species, and also supplied a series of determined parasites of the genus. Mr. Warren Knaus has determined numerous specimens of genera other than *Phyllophaga.*

In addition to a biological consideration of the species, a morphological study of the adult of *Phyllophaga crassissima* Blanch. has been carried on in connection with these studies and the results have been reported elsewhere (Hayes, 1922). The difficulty of identifying the larvæ or white grubs of the family is well known. Believing that a thorough morphological study of the various species will reveal characters by which they can be separated, the writer has under way a study of this nature. Some of the results obtained in this phase of the work have been submitted as an unpublished minor thesis to the graduate faculty of Cornell University.

The Life History of the Melolonthinæ

This important subfamily contains two well known genera, *Melolontha* and *Phyllophaga* which are of decided economic importance. Fortunately, Melolontha with its destructive species *M. melolontha* does not occur on the American continent, but in its place we have the genus *Phyllophaga* with its numerous species, many of which are noted for their injuries to the roots of crops and the foliage of trees and shrubs. Two other genera may cause considerable damage, at least in the adult stage. These are *Diplotaxis* and *Serica,* concerning which practically nothing is known of their life history. In India, *Serica assamensis* is a serious enemy of sugar-cane. Certain species of the genus *Lepidiota* also attack sugar-cane in Australia and Java. In the West Indies a destructive species of this subfamily is *Phytalis smithi,* likewise a pest of sugar-cane.

The length of the life cycle of members of this group is extremely variable. It has long been known that in Europe the cockchafer, *Melolontha melolontha,* requires a period of three years for its development in France and southern Germany, while in northern Germany four years are needed. In Porto Rico, it has been found that *Phytalus smithi* has a life cycle of slightly over a year.

Although the species of *Phyllophaga* have been known as important pests for a number of years, only scanty information has been available concerning their life histories, particularly with reference to the length of the various stages. This is due, in a large measure, to the fact that practically all of their period of development is spent beneath the surface of the soil where it is difficult to observe their life activities. Chittenden (1899) was the first to report the rearing of a species of this genus. He found, in the case of one individual of *P. fervida* that 781 days were required from the date of egg laying to the transformation of the pupa to the adult. This makes a life cycle of three years for the species. Davis (1916) reported on the length of the life cycle of 18 species of the genus, and in his summary notes that one species, *P. tristis,* invariably has a two-year period in the region of Lafayette, Ind., and eleven other species, namely, *P. fervida, P. fusca, P. vehemens, P. rugosa, P. ilicis, P. grandis, P. fraterna, P. hirticula, P. inversa, P. bipartita,* and *P. congrua* without exception have a three-year life cycle. Two species, *P. crenulata* and *P. crassissima,* have a three-year cycle that may be extended to four years, and certain other species as *P. futilis, P. ephilida,* and *P. implicata* ordinarily have a three-year cycle that is often reduced to two years. From this it can be seen that the more important species have, in the latitude of Lafayette, a three-year cycle. Smyth (1917) has found that the life cycle of *P. vandinei* occupied approximately one year in Porto Rico. These citations contain practically all our knowledge of the life cycle of members of the genus, and except for the work of Smyth very little is said concerning the length of the different immature stages.

In the present study, efforts have been exerted to work out as many of the species as possible as they occur in Kansas. Thus far 17 species have been reared from egg to adult, of which six have not been heretofore studied. To generalize, it can be asserted that the results are in accord with those of Davis in showing a decided variation of the length of the life cycle in most of the species, this variation being found in the length of the larval period. For example, some species have, in the vicinity of Manhattan, either a one-, two-, or three-year life history. The results obtained on *P. lanceolata, P. rubiginosa, P. futilis, P. rugosa, P. implicata, P. vehemens,* and *P. submucida* have been reported by Hayes. Nine additional species are herein considered and further data are given on *P. vehemens* which has previously been discussed.

THE LIFE HISTORY OF THE GENUS PHYLLOPHAGA

The genus *Phyllophaga* is confined almost entirely to the Western Hemisphere where it extends from the Hudson Bay territory south to Argentine. It is closely allied to *Melolontha* of Europe and Asia, *Rhizotrogus* and *Holotrichia* of Asia, and *Listrochelus* of the United States and Mexico. The catalogue of Dalla Torre (1912) lists approximately 232 species belonging to the genus and a large per cent of them are from the United States.

The distinguishing characters by which the genus can be recognized are the transverse front coxæ, which are not prominent; six ventral segments, firmly united yet with the sutures visible; the tarsal claws, never serate, but with a single tooth beneath; long, often dense hairs on meso and metasterna; elytra without striæ or grooves over the greater portion of the disk; pale reddish or yellowish-brown to piceous color; usually large.

The genus has been commonly known to American and English entomologists under the name *Lachnosterna* Hope and by other European workers as *Ancylonycha* Dejean. The name *Phyllophaga* was proposed by Harris (1826) who says:

"The genus *Melolontha* as constituted by Fabricius contains a vast number of species, differing greatly in external appearance, and somewhat in modes of life. Fabricius describes 149 species, and Schoenherr, after separating those which constitute the genera *Anisonyx, Glaphyrus, Amphicoma, Rutela* and *Hoplia* enumerates 226 species of *Melolontha,* to which additions are constantly made by the discovery of new species. Hence the genus requires further subdivision. The basis of these subgenera have already been pointed out by Latreille, Knoch, and Schoenherr, and some have already been established. I would restrict the name of *Melolontha* to those species which have more than three lamellæ to the club of the antennæ, like the *vulgaris* of Europe, and of which we have an indigenous example in the *M. decimlineata* of Say (*M. occidentalis* Herbst?). Our common species *quercina, hirsuta, hirticula, balia,* and some others might receive the generic name Phyllophaga."

LeConte (1856) after a consideration of the history of these names was convinced that, for the sake of purity in nomenclature, the name Lachnosterna should be adopted, and that *Phyllophaga* and *Ancylonycha* should be rejected since they were not supported by valid descriptions to indicate the limits of the genus. Lacordaire (1856) was in accord with this view and pointed out that the name *Phyllophaga* Harris was a *nomen nudum* and should therefore be rejected.

The name Phyllophaga was revived by Glasgow (1916) "on the ground that its validity was fully established by its publication in connection with a series of valid specific names." In lieu of a des-

ignated genotype, he proposed that *hirticula* Knoch serve as the type of the genus. His argument for the change is supported by the International code. This much regretted change has been adopted rather hesitatingly by American workers while certain English entomologists refusing to recognize its validity still maintain that it is a *nomen nudum* and retain the name Lachnosterna.

Glasgow (loc. cit.) has made a thorough study of the synonymy of the American species of the genus. The names concerned in the present study are based on Glasgow's work and the synonymy given in the catalogue of Dalla Torre (1912). The order of discussion follows the arrangement of Leng (1920).

Phyllophaga Praetermissa Horn

Description of Adult and Synonymy.—Horn (1887) described this species from male specimens collected in Louisiana. In the following year, Smith (1888) described the same species under the name *definita* and in 1916 Glasgow recognized their similarity and placed the name *definita* in synonymy. Horn's original description of the adult is as follows:

"Oblong, slightly broader behind, dark rufotestaceous to piceous brown, usually paler beneath, moderately shining. Clypeus feebly emarginate, the border narrowly reflexed; surface moderately, coarsely, sparsely punctate, front similar. Thorax obliquely narrowed in front, the sides posteriorly either parallel or slightly sinuate, the margin sparsely ciliate, not crenate, punctures moderately coarse, irregularly placed, with a tendency to form groups, median region somewhat smoother. Elytral punctures larger and closer than those of the thorax, somewhat stellate, the surface slightly wrinkled, the discal costæ very indistinct, the submarginal feeble posteriorly. Pygidium convex, the punctures finer and sparser than on the thorax. Metasternum densely punctulate, the hair rather long and dense. Abdomen at sides finely sparsely punctate, the last two segments more coarsely punctate. Last joint of maxillary palpi shortly fusiform, not impressed. Claws arcuate, a strong acute tooth at middle. Length .58 to .64 inch; 15 to 16 mm."

The specimens show little variation except in color and size. The club of the antenna is as long as the stem in the male and considerably shorter in the female. The abdomen (Pl. IV, fig. 1A, B) in the male is slightly flattened in the middle, the next to the last segment bears a slightly roughened ridge near the posterior border, the last segment is concave and broadly emarginate at the apex. The female has the abdominal segment convex with the last segment depressed and emarginate on the posterior margin. The genitalia of the female, important structures in classification, are shown on Plate IX, figure 4.

Distribution.—*P. prætermissa* is more commonly found in the southern states. It was originally described from Louisiana. Forbes (1916) records it from southern Illinois. Kansas and Illinois are perhaps the northern limits of its range. Dalla Torre (1912) adds Florida, Kentucky, and South Carolina to its known distribution and Manee (1909) reports it uncommon in North Carolina. The collection of the Kansas State Agricultural College contains a specimen from Agricultural College, Miss.

In these studies, specimens were found in Riley, Sumner and Sedgwick counties, Kansas, and the Knaus collection has examples from Wilson, McPherson, and Reno counties, Kansas.

Relative Abundance.—The relative abundance of this and other species herein discussed is based on the collections made at lights, on food plants, in the soil and miscellaneous situations during the period from 1916 to 1922. It includes also specimens reared from collected grubs and from eggs in the life history studies.

These studies indicate that *P. prætermissa* is not common in the area under observation. It ranks sixteenth among the total species taken. In all, only 115 specimens were collected and of these 93 were collected at lights, 18 from food plants, 3 in the soil and 1 was found crawling on the surface of the soil. In addition, 12 were reared from grubs and 2 from eggs, making a complete total of 129 individuals considered in this work. It is apparent from these figures that this species is not of particular importance in Kansas.

Attraction to Lights.—Special attention has been devoted to the attraction of the beetles to lights. Practically all of the species of *Phyllophaga* are more or less attracted, and it seemed that systematic collections at street lights would prove the best criterion of the species present, their relative abundance, local distribution, period of flight, succession of species, and proportion of sexes. Because of the fact that trap lights are frequently recommended as a control measure, it was deemed advisable to make a comparison of the numbers found at lights with those found on food plants. Accordingly, regular nightly collections were made each year around street lights from the opening to the close of the flight season.

It was found that all of the species of *Phyllophaga* here treated are nocturnal in their habits of flight. One exception to this rule, a diurnal species, *P. lanceolata,* occurs in Kansas and is very abundant. Excepting this species, the beetles of *Phyllophaga* emerge from the soil soon after sunset and may be found flying around lights, crawling on the surface of the soil, or feeding on

their preferred food plants until just before sunrise. Linton (1888) and Schwarz (1891) have described flights of two species, *P. tristis* and *P. crassissima,* which began in the case of *tristis* shortly after sunset and with *crassissima* before dark.

P. prætermissa is more numerous at lights than elsewhere, over 80 per cent of the total collections having come from this source.

Period of Flight.—The duration of the flight season varies with the season and the species concerned. This species is not represented by numbers sufficiently large to determine accurately the period of flight. The earliest record of its flight at Manhattan is May 16 and the latest is June 12. Forbes (1916) records the flight period in southern Illinois from May 14 to June 22, and Manee (1909) has noted that it flies in North Carolina in early April.

Soil Preferences.—A study of the soil preferences of the beetles can only be made by collecting them behind the plow or by digging them. Such data, although difficult to obtain, serves as a clue to the food preferences of the grubs.

The data show that *P. prætermissa* is more frequently encountered in native prairie and sod land, especially lawns. Four adults were reared from grubs collected in the native prairie grass sod of the Kansas State Agricultural College campus. Adults have also been collected in land planted to wheat and to corn.

Food Habits.—In order to ascertain the food relations of the various species of *Phyllophaga,* systematic collections were made from food plants during the years 1916 to 1920. An effort was made to select definite plants and to collect from these during the entire period. In addition, many general collections were made. During this period, 37,655 beetles, representing 22 species, were taken on food plants.

It was found that certain varieties of plants are particularly attractive to a large number of species, and are always subject to injury, while others may be comparatively immune to attack and are rarely visited by the beetles. Forbes (1916) has shown that there may be a direct relation between the plants present in a certain area and the amount of injury caused by white grubs.

Of the 129 individuals of *P. prætermissa* considered in this report, only 18 were found on plants. Of these, nine were found on Jersey tea and lead plant, three on elm, two on dogwood, one on cedar, one on *Œnothera,* and one on a dead iris blossom. (Table I.)

Forbes (1916) has likewise found this species to be rare on food plants. He collected 26 beetles, 13 of which came from oak, nine

from willow and four from apple. Manee (1909) found the beetles around gummy oak buds. The Kansas State Agricultural College collection contains a specimen taken on pecan in Mississippi. The females of this species do not always fly, but may crawl to their food plants, since one specimen was observed to do this in a meadow with considerable Jersey tea and lead plant, two of its observed food plants.

Proportion of Sexes.—The males of *Phyllophaga* are commonly considered to be the more abundant at lights than the females, and females more abundant on food plants. To determine this point, records were kept of the sex of most, but not all, of the beetles collected, and these are summarized in Table LIX. It was found that the males were more numerous at lights in the case of all species except *implicata, longitarsa,* and *prætermissa.* This is important from the standpoint of the recommendations of the use of trap lanterns and explains to some extent why trap lights are not efficient in control work.

In regard to the collections on food plants, there is a more equal distribution of males and females, and in some cases (*corrosa* and *hirticula,* Table LIX) the females predominate.

P. prætermissa is represented by more females than males, 64.3 per cent of the 129 beetles taken being females. The proportion of males and females from different sources is shown in Table I.

TABLE I.—The proportion of sexes of *P. prætermissa.*

SOURCE.	Total number of individuals collected.	Number of females.	Number of males.	Per cent females.
At lights	93	66	27	7
On food plants	18	9	9	50
In soil	3	1	2	33
Miscellaneous collections	1	1	0	100
Reared from grubs	12	5	7	42
Reared from eggs	2	1	1	50
Total	129	83	46	64

Description of Eggs.—The eggs of all species of *Phyllophaga* are very similar except for size. They are white in color and when freshly laid are oval in shape. They are deposited singly in the earth and are surrounded by an earthen ball, the particles of which

are held together by a secretion probably from the colleterial glands of the female. As development proceeds, an enlargement, accompanied by a slight increase in weight, occurs which causes the eggs to assume a more globular shape. Daily measurements of the eggs show a gradual increase in size during the earlier periods of development until the final measurement is to the initial measurement as seven is to five.

The eggs of *P. prætermissa* are approximately 2 mm. long and 1.5 mm. wide, and as development proceeds they become more spherical and increase in size to 3.25 mm. in length by 2.25 mm. in breadth.

Length of the Egg Stage.—The length of the egg stage of this species was determined in 1920 for 185 eggs. The longest period of development was 23 days and the shortest was 12 days with an average for the 185 of 17.8 days.

Description of Larva.—The larvæ of all species of the genus are so nearly alike that a description here will suffice for all of the species which follow. Davis (1916) has supplied us with a good description and it is here quoted:

"The *Lachnosterna* grub is white or cream white, the dark contents of the intestinal tract being plainly visible through the skin of the last abdominal segments. The head is light tan in color, smooth and shiny and the body is covered with reddish brown hairs, those on the dorsum of the folds or ridges being short and more thickly placed. The ventral surface of the anal segment, which shows the most prominent character, bears a triangular patch of brownish hairs which are hooked at the tip, with an intermixing, especially at the borders of the patch, of fine, long hairs, and with a median longitudinal double row of coarse hairs or spines inclined more or less inwardly. These rows may be straight or parallel or more or less curved; short or long; and the spines in the rows may be sparsely or closely placed according to the species. The anal slit is in the form of an obtuse angle."

Length of Larval Stage.—The number of grubs under observation of *P. prætermissa* has been small and although the data are not extensive they show that this species has a two- and a three-year cycle. Of the thirteen larvæ carried beyond the second molt only two indicated a two-year period. The first molt was found to occur the same year as hatching, while the second molt may occur during the same season as the first or be postponed to the following or second summer. When the two molts occur the same season, the grub completes its growth the following year and pupates, thus having a two-year period. If the second molt does not occur until the second season, the grub remains active until the third summer when it pupates, thus requiring three years for development. In other

words, when the two molts occur during the summer in which the egg hatches, a period of two years is required to mature, and when the second molt is delayed until the succeeding summer, three years are needed.

Table II summarizes the data obtained relating to the larval stage of this species.

TABLE II.—The length of the larval stage of *P. prætermissa.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	16	49	19	35.8
First molt to second molt	16	374	20	263.0
Second molt to prepupa	5	429	320	397.6
Active larval stage	5	772	390	692.0
Prepupal stage	15	12	3	6.7
Total larval stage	4	780	395	680.0

. It will be noted that five individuals were carried through the active larval stage, that is, up to the time of the prepupal stage when the grub becomes inactive. One of these died in the prepupal stage and accordingly data on the complete larval stage are had on but four individuals. The numbers in the prepupal stage are augmented by eleven records from grubs collected in the fields.

The period between hatching and the first molt is seen to vary from 19 to 49 days with an average of 35.8 days. The molt occurs the season in which the egg hatches. The time between the first and second molt is more variable because the grub may molt the first season in the case of the two-year grubs or be postponed until the following summer in instances where development is to require three years. The table shows that as few as 20 days or as many as 374 days may pass before the second molt occurs. The average for the 16 individuals observed was 263 days. The period between the second molt and the time when the grub enters the prepupal condition, for five individuals, was found to vary from 320 days to 429 days with an average of 397.6 days.

The prepupal stage of 15 specimens ranged from three to twelve days with an average of 6.7 days. For the four specimens reared through the complete larval stage, there was a range of from 395 to 780 days with an average of 680 days.

Food of the Grubs.—The food of the grubs as determined in

these studies is the roots of native prairie grasses and lawn grasses. The fact that one adult was collected in wheat stubble at Wichita, March 13, indicates that it had developed there, perhaps at the roots of the wheat.

Length of Pupal Stage.—The pupal stage of 13 specimens of *P. prætermissa* has been recorded. It was found to vary from 21 to 28 days with an average of 24.9 days. Pupation takes place during August and the adults transform the last of that month or in September. A freshly transformed adult collected behind the plow August 7, indicates that the pupæ may transform earlier than that date.

Life Cycle.—Only two individuals of this species were reared from eggs through all stages to maturity. These eggs were deposited in 1920. One individual had a two-year cycle of 434 days and the other had a three-year cycle of 811 days. If we compute the average length of the egg, larval, and pupal stages of Table III, we obtain a minimum period of development of 428 days and a maximum period of 831 days. These figures are not far from the actual length of the two specimens reared through all their stages. The figures are computed for the life cycle as shown in Table III.

TABLE III.—The computed life cycle of *P. prætermissa.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg stage	185	23	12	17.6
Larval stage	4	780	395	680.0
Pupal stage	13	28	21	24.9
Life cycle		831	428	722.5

Phyllophaga Longitarsa Say

Description of Adult and Synonymy.—This species, probably because of its habitus, has not been involved in complicated synonymical changes. LeConte described a species *frontalis* which Horn (1887) says can hardly be considered a variety. Burmeister (1855) has cited *glaberrima* Blanch, as a synonym but Horn regards it as a distinct species and is so considered by Glasgow (1916) who, however, did not see the type in his study of the synonymy of the genus. Burmeister discussed the species in the genus *Trichestes* Erichs. In general appearance it is strikingly different from the common species of Phyllophaga and to the ordinary observer would

appear rather as belonging to the genus *Ochrosidia*. It was described as *Melolontha longitarsis* by Say (1824) in the following words:

"Pale, cinerous-testaceous; clypeus profoundly emarginate; tarsi elongated."

"*L. longitarsis* Say. Slender, elongate, cylindrical, pale yellowish testaceous, front fuscous or piceous; surface moderately shining. Clypeus concave, deeply emarginate, surface shining, coarsely very sparsely punctured, front coarsely densely punctured. Thorax short, transverse, strongly arcuate in front, slightly sinuate, margin entire, fimbriate in front, surface somewhat irregular, the punctures coarse not deep, rather closely placed. Elytra coarsely punctured, the punctures rather shallow, sparser near the apex, the discal costæ very feeble, the submarginal moderately well defined. Pygidium ♂ with coarse shallow punctures, those of the ♀ finer and more sparse near the apex. Metasternum closely, but indistinctly punctate, the hairs moderate in length but sparse. Abdomen sparsely indistinctly punctate at the sides, the last two segments more coarsely punctured. Last joint of maxillary palpi short, fusiform, very distinctly impressed. Claws feeble curved ♂ and with a small acute tooth near the base, the ♀ claw more arcuate, the tooth stronger and median. Length .41 to .52 inch; (10.5 to 13 mm.)."

Some specimens exhibit variation in the color of the head which may be pale brown or nearly black. The club of the antenna of the male is a little longer than the stem, and in the female it is shorter. The abdomen of the male (Pl. IV, fig. 2A) is somewhat flattened at the middle and the last segment is irregularly concave; while the last ventral segments of the female (Pl. IV, fig. 2B) on the contrary, are decidedly convex with the last segment emarginate posteriorly. The tarsi of the third pair of legs are shorter in the female than in the male. The genitalia of the female are shown in Plate IX, figure 1.

A specimen in the Knaus collection from Columbus, Tex., has the clypeus more strongly punctured than the Kansas forms. The longitudinal depression of the front is deeper and more impunctate; the clypeal frontal suture is more sinuate; and the specimen is somewhat darker in color, but the genitalia are similar.

Distribution.—This species is recorded from a number of widely separate localities, but is not common in any of them. It is apparently indigenous to the prairie and Great Plains regions. Say described the species from Missouri. It is said by Horn (1887) to occur from Illinois to Kansas and Montana and southward to New Mexico, and Smith (1910) records it from New Jersey. King (1914) has noted it from Henry county, Iowa. Forbes (1918) observed it in only one locality in southern Illinois, and Blatchley (1910) states that it is rare in Indiana. The Knaus collection contains specimens from New Mexico and Texas and the Cornell collection

has two specimens from the Crew collection without locality labels. The distribution in Kansas, as indicated by the specimens studied, is Riley, Geary, Sedgwick, and Wallace counties.

Relative Abundance.—Of the 25 species of *Phyllophaga* found in the area under discussion, this species ranks eleventh in relative abundance. In all, 909 specimens have been handled. Of these 904 were obtained from lights, 1 from food plants, 1 from soil, and 3 from miscellaneous collections. In addition, three beetles have been reared from grubs collected in the field and 48 have been reared from eggs in the life history cages.

This species has not been known to be injurious in Kansas or in other localities where it occurs. From the meager data at hand, it appears that it prefers the sandy soils of the regions in which it occurs.

Attraction to Lights.—*P. longitarsa* is fairly common at lights during July, over 99 per cent of the collections having been from this source. It is apparently attracted to the stronger lights, for most of the specimens collected in Manhattan were from the business part of the city.

Period of Flight.—This is one of the late-flying species, the earliest date on which it has been taken being June 18. As a general rule the flight is over by the middle of August, although in 1920 specimens were collected as late as September 2. Forbes (1916) found specimens July 12 in Illinois and Blatchley (1910) records a collection in Indiana on July 28. Table IV shows the period of flight at Manhattan during the years when it was sufficiently abundant to warrant drawing conclusions.

TABLE IV.—The period of flight of *P. longitarsa*.

YEAR.	1917.	1920.	1921.	1922.	Average date.
First flight	July 6	July 2	June 18	June 19	June 26
Maximum flight	July 20	July 17	July 7	July 12	July 14
Last flight	Aug. 2	Sept. 2	Aug. 11	Aug. 5	Aug. 13
Period of flight	27 days	62 days	54 days	47 days	48 days

Soil Preferences.—The data regarding soil preferences are meager. One beetle was collected under drift on the sand dunes of the Kansas river and three were reared from grubs collected in the same situation. These collections indicate that the species may prefer the sandy situations, as none were found among the thousands of grubs of other species collected in other places.

Food Habits.—Here again the data are meager. Only one beetle was collected on food plants. This was taken on an elm in 1917. Adults confined in cages in the laboratory fed on apple, peach, and cottonwood. Forbes (1916) did not find this species on plants during the course of his work in Illinois.

Mating and Oviposition.—The process of mating of this species has not been observed in nature, but was noted several times in the rearing cages where the beetles were under abnormal conditions. The act differed from that observed in other species of the genus in that the male did not hang suspended away from the female by its genitalia, but remained on the back of the female, clasping it with the fore and middle tarsi.

The period of oviposition, as determined from beetles in the laboratory cages, was noted in 1921 to extend from June 22 to August 24, a period of 63 days.

Proportion of Sexes.—The females have been the more numerous in the collections, and especially those from lights. The sex ratio of 956 beetles has been noted. This figure is larger than the total collections, because of the addition of 48 beetles reared from eggs in the laboratory. The relative numbers of the two sexes are shown in Table V.

TABLE V.—The proportion of sexes in *P. longitarsa*.

SOURCE.	Total.	Females.	Males.	Per cent females.
At lights	900	573	327	63
From food	1	0	1	0
From soil	1	1	0	100
Miscellaneous	3	1	2	33
Reared from grubs	3	2	1	66
Reared from eggs	48	29	19	60

Description of Eggs.—The egg of this species, like the others, is oblong-oval in shape when freshly laid, but gradually changes in form to globose. It is pearly-white in color and approximately 2 mm. long and 1.25 mm. in diameter.

Length of Egg Stage.—The length of the egg stage of *P. longitarsa* has been determined for 447 eggs and has been found to average 12.7 days with extremes of 7 and 19 days. The data on this point for five years are summarized in Table VI.

TABLE VI.—The length of the egg stage of *P. longitarsa.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1917	1	13	13	13
1918	2	13	10	11.5
1920	120	19	10	13.8
1921	188	17	9	11.8
1922	136	19	7	13.2
	447	19	7	12.7

The earliest date on which eggs were deposited was June 22, and hatching was noted to continue as late as September 10.

Length of Larval Stage.—Owing to the shorter life-cycle of this species, it has been possible to rear a larger number of the larvæ to maturity and the data on the length of the larval stage may be considered fairly reliable. With one exception, all of the grubs completed their development in less than a year. The first and second molt occur the same year as hatching. Growth is usually completed the early part of June in the year following that of hatching. The data relating to the length of the larval stage are recorded in Table VII.

TABLE VII.—The length of the larval stage of *P. longitarsa.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	67	42	17	24.1
First molt to second molt	67	286	11	69.7
Second molt to prepupa	67	388	35	270.6
Active larval stage	67	691	298	340.0
Prepupal stage	58	16	2	4.1
Total larval stage	62	671	300	337.0

It will be noted that the average period between hatching and the first molt was 24.1 days and from the first to the second molt 69.7 days. The longest period is between the second molt and the time that the prepupal condition is assumed, which on the average was 270.6 days. The total active stage varied from 298 to 691 days, with an average of 340 days. The prepupal stage lasts from

2 to 16 days, and the total larval stage, including the prepupal, required from 300 to 671 days, with an average of 337 days.

Description of Pupa.—The pupa when freshly transformed is creamy-white in color and gradually changes during development to a pale yellow. It is about 24 mm. long and 7 mm. wide.

Length of Pupal Stage.—The length of the prepupal stage was determined for 50 individuals and was found to average 13.4 days with extremes of 17 and 6 days. Pupation may occur at any time between June 1 and July 24.

Life Cycle. — Forty-eight adults of *P. longitarsa* have been reared from eggs and with one exception the life cycle was about one year. The maximum length of the life cycle was 701 days and the minimum 327 days. A grub which had an active larval stage of 691 days and reached the prepupal stage the second year, indicates that a two-year cycle may occur occasionally. Table VIII shows the length of the life cycle determined by actual rearings, and Table IX is computed from the extremes and averages of each stage.

TABLE VIII.—The life cycle of *P. longitarsa.*

LIFE CYCLE.	Number reared.	Number of days.		
		Maximum.	Minimum.	Average.
One-year cycle	47	389	327	356.4
Two-year cycle	1	701	701	701.0

TABLE IX.—The computed life cycle of *P. longitarsa.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg stage	477	19	7	12.7
Larval stage	62	671	300	337.0
Pupal stage	50	17	6	13.4
Life cycle		707	313	363.1

Phyllophaga Bipartita Horn

Description and Synonymy.—Horn (1887) described *Phyllophaga bipartita* in the old genus *Lachnosterna,* and because of its comparatively recent advent it has not been involved in synonymy. Horn's description of the adult follows:

"Oblong, slightly oval, casteanous to piceous, moderately shining. Clypeus broadly, but feebly emarginate, margin moderately reflexed, the punctures coarse and rather close, front more coarsely and densely punctured. Thorax moderately convex, narrower in front, sides posteriorly nearly straight and parallel, anteriorly arcuately and obliquely narrowing to the front, the margin crenate and with short ciliæ, the punctures coarse and moderately close, near the sides somewhat larger and more distant, median line usually smooth, a slight impression of the basal margin each side. Elytral punctures as coarse and close as those of the thorax, indistinct and rugulose each side of the suture, the sutural and first distal costæ fairly distinct, the others very indistinct or entirely wanting. Pygidium sparsely indistinctly punctate. Metasternum densely punctured, the hair moderately long and dense, less dense in ♀. Abdomen sparsely punctate. Claws arcuate, the tooth median and strong in both sexes. Last joint of maxillary palpi very slightly fusiform, not impressed. Length .60-75 inch; 15-19 mm."

In the male the antennal club is as long as the stem and in the female shorter than the funiculus. The abdomen of the male is longitudinally impressed at the middle, and the next to the last segment has an acute transverse carina which is divided into two parts by the longitudinal impression. The last segment has an acute emargination on the posterior edge and the segment as a whole is slightly concave (Pl. IV, fig. 3A). The last ventral segment of the female is sinuate on each side of the middle so that the middle projects in the form of a broad triangular tooth and the segment is slightly rugose. The penultimate segment bears a faint transverse ridge (Pl. IV, fig. 3B).

Variation may be found in some specimens in that the smooth space on the thorax is not always distinct, and the costæ of the elytra may vary slightly in distinctness. The size of the transverse ridge on the next to the last segment of the abdomen may so vary in development that at times the free edges of the carina may appear as overhanging lobes.

Distribution.—*Phyllophaga bipartita* is confined to the central and southern states of the Mississippi river valley. Horn (1887) described the species from specimens collected in Kansas, Louisiana, and Texas, and Smith (1888) added Tennessee and Missouri. Forbes (1916) found it to be a common species in southern Illinois, but extremely rare in the central part of the state. Montana has been added by Dalla Torre (1912) but this record seems doubtful. The Knaus collection contains specimens from Tennessee and the Cornell collection has one example from the Crew collection with no locality label.

In Kansas, the species seems to be generally distributed over the

eastern part of the state. Specimens have been collected or seen from Sumner, Cowley, Wilson, Sedgwick, Butler, Reno, Cloud, McPherson, Douglas, and Riley counties.

Relative Abundance.—This is one of the most common species of Riley county, ranking seventh in total numbers collected. It is, without much doubt, primarily a prairie species, being most commonly found in such situations. During the course of these studies, 3,596 specimens have been secured, of which 2,709 came from lights, 836 from food plants, 17 from the soil, and 27 from miscellaneous sources. Four beetles, included in the total, were reared from collected grubs and three were reared from eggs.

Attraction to Lights.—The males of *P. bipartita* are readily attracted to lights and constitute 97.6 per cent of the total light collections of this species. The females are taken at lights only rarely, comprising only 2.4 per cent of the total and were not represented in the 1918, 1919 or 1921 collections. Knaus (1901) also found the males predominating at lights at McPherson. Although the period of flight usually covers from 30 to 60 days, the largest flights occur during a few nights only each year. In 1917, these large flights were on May 29, June 7, and June 10, while in 1920 they occurred May 24, May 26, and June 6 to 9.

Period of Flight.—The earliest date on which beetles of this species were collected in flight was May 5, 1922, and the latest flight was July 24, 1917. The average period of flight, based on seven years collecting, was 39 days. The maximum period of activity has varied in the several years from May 20 to June 7. Forbes (1916) records the flight period in southern Illinois from April 15 to June 30 and the Kansas records show that emergence may occur as early as April 24 at Winfield. The pertinent data concerning this point are shown in Table X.

TABLE X.—The period of flight of *P. bipartita*.

YEAR.	1916.	1917.	1918.	1919.	1920.	1921.	1922.
First flight	May 22	May 17	May 14	May 15	May 10	May 17	May 5
Maximum flight	May 22	June 7	May 27	May 24	June 7	May 23	May 20
Last flight	June 1	July 24	July 4	June 17	July 5	June 7	June 7
Period of flight	10 days	68 days	51 days	33 days	56 days	21 days	33 days

Soil Preference of Adults.—The soil collections, while not extensive, indicate that this species prefers the native sod land of the high prairies. Seventeen adults have been collected in the soil, twelve coming from native sod, three from gardens and two from corn land. An adult was collected in a cornfield at Winfield, and two were found in drift washed from an alfalfa field. The rearings from collected grubs also indicate a preference for the high prairie.

Food Habits.—This species (*P. bipartita*) is a rather general feeder, having been taken on 36 different plants. A decided preference was shown for low-growing vegetation found on the high prairies. The beetles of this species, especially the females, crawl to their food plants instead of flying. The principal food plants are shown in Table XI.

TABLE XI.—The food plants of *P. bipartita*.

PLANT.	Number of beetles.	Per cent of total.	PLANT.	Number of beetles.	Per cent of total.
Miscellaneous weeds	250	28	Buffalo pea	10	1
Walnut	117	13	Dock	8	*
Cedar	83	9	Jersey tea	8	*
Wild rose	63	7	Indian coral	6	*
Locust	62	7	Willow	7	*
Verbena stricta	54	6	Iron weed	5	*
Lead plant	35	4	Apple	4	*
Elm	34	4	Redbud	3	*
Oak	25	2	Miscellaneous	23	2
Foxtail	14	1			
Dogwood	14	1	Total	836	.....
Iris (dead)	11	1			

* Less than one per cent.

In addition, one or two specimens were taken on peach, birch, peppergrass, alfalfa, boxelder, cottonwood, sage, sumac, catalpa, ash, silver poplar, hawthorn, wild grape, and hickory. It is interesting to note that 22 females and 30 males were taken while feeding on new mown hay, and that 11 beetles were found on dead iris on a grave. The Kansas collection contains specimens from a hay meadow collected in 1895. One male at Dwight, Kan., was found feeding on elm.

Forbes (1916) considers *P. bipartita* primarily a willow species, since 86 per cent of his food plant collections were from this plant.

Table XII shows the food plants as found by Forbes in Illinois compared to the relative abundance on these same plants in Kansas. It should be borne in mind that hickory and willow are relatively more abundant in Illinois than in Kansas.

TABLE XII.—The food plants of *P. bipartita* in Kansas and Illinois.

PLANT.	Illinois.	Kansas.
	Per cent.	*Per cent.*
Willow	86.0	0.8
Hickory	8.0	0.1
Oak	4.2	3.0
Apple and persimmon	1.8	0.4
Total number collected	645	832

Proportion of Sexes.—The males have predominated in nearly all collections as shown in Table XIII which includes all specimens the sex of which was recorded. This is especially true in the case of collections at lights where they represent 97.8 per cent of the total. In 1917, only 0.6 of 1 per cent of the light collections were females, while none appeared in the 1918, 1919, and 1921 collections. The females were well represented in the collections from food plants, especially from low-growing vegetation.

TABLE XIII.—The proportion of sexes in *P. bipartita.*

SOURCE.	Total.	Females.	Males.	Per cent females.
Lights	2,659	60	2,599	2
Food plants	832	317	515	38
Soil	16	6	10	37
Miscellaneous	27	18	9	66
Reared from grubs	4	4	0	100
Reared from egg	3	1	2	33
Total	3,541	406	3,135	11

Mating and Oviposition.—Mating has been observed frequently in this species and in each instance it occurred on low-growing vegetation. The plants from which pairs in copulation have been taken are foxtail, *Verbena stricta,* ironweed, sage, cedar, wild rose, and walnut sprouts. Mating occurred from May 18 to June 29 in 1920.

On May 19 large numbers were taken in copulation on a small patch of foxtail on a native prairie.

Eleven females confined in individual cages deposited an average of 17.6 eggs with extremes of 31 and 3. In 1920 egg laying began May 31 and ended August 4.

Length of Egg Stage.—The data regarding the length of the egg stage of *P. bipartita* obtained in 1919 and 1920 are shown in Table XIV.

TABLE XIV.—The length of the egg stage of *P. bipartita.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1919	8	19	15	17.1
1920	254	24	11	16.6
	262	24	11	16.8

It will be seen that the average length of the egg stage for 262 eggs was 16.8 days, with a maximum of 24 days and a minimum of 11 days.

Length of Larval Stage.—The length of the various instars of *P. bipartita* are shown in Table XV.

TABLE XV.—The length of the larval stages of *P. bipartita.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	100	63	11	39.9
First molt to second molt	34	335	284	309.9
Second molt to prepupa	9	423	70	337.2
Active larval stage	9	781	405	683.0
Prepupal stage	9	17	3	9.2
Total larval stage	6	788	411	707.2

In every case the first molt occurred the same year that the grub hatched, and the second molt the following year. The time of molting was fairly constant, the first molt occurring about the middle of August and the second molt the following June. Of the nine larvæ reared to prepupæ, seven represented a three-year life cycle and two were two-year grubs.

From Table XV it may be seen that the average period between the time of hatching and the first molt was 39.9 days and from the first to the second molt 309.9 days. The longest period is between the second molt and the prepupal period, which averaged 337.2 days. The total active stage of the larvæ varied from 405 days to 781 days, with an average of 683 days. The prepupal stage varied from three to 17 days and the complete larval stage from 411 to 788 days, with an average of 707.2 days.

Food of Grubs.—The principal food of the grubs appears to be the roots of grasses. Four adults were reared from grubs collected in the field. Three of these came from the roots of native prairie grass, while the other came from the roots of foxtail.

Description of Pupa.—The pupa of this species measures 22 to 23 mm. in length and 9 mm. in width.

Length of Pupal Stage.—The length of the pupal stage was determined in six cases, three of which were reared from collected grubs. It was found to vary from 24 to 35 days, with an average of 30.3 days. The date of pupation has varied in the different years. In 1919 and 1922 pupation occurred in August while in 1920 it did not begin until September. The length of the pupal stage also varies with the date of pupation as shown by Table XVI.

TABLE XVI.—The length of the pupal stage of *P. bipartita*.

DATE PUPATED.	Date emerged.	Length of stage.
August 12, 1922	September 5, 1922	24 days.
August 21, 1922	September 15, 1922	25 days.
August 23, 1919	September 22, 1919	30 days.
September 6, 1920	October 9, 1920	33 days.
September 8, 1920	October 13, 1920	35 days.
September 18, 1920	October 22, 1920	35 days.

Life Cycle.—Three individuals were reared from egg to adult. Two of these were apparently three-year beetles, requiring 799 and 815 days. The other was a two-year beetle requiring 495 days. Of nine larvæ reared to prepupæ, seven represented a three-year cycle and two a two-year cycle. Table XVII shows the calculated life cycle computed from the data for each stage.

TABLE XVII.—The computed life cycle of *P. bipartita.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	262	24	11	16.6
Larval	6	788	411	707.3
Pupal	6	35	24	30.3
Life cycle		847	446	754.2

Phyllophaga Vehemens Horn

Description and Synonomy.—This species so resembles *P. fusca* Frohl., the next species to be discussed, that it can be distinguished from it only with difficulty, and were it not for their quite distinct genitalia, the confusion would be even greater than is normally the case. Fortunately, *P. vehemens* has not been confused with other species and has been involved in no changes in synonymy. This is due, in part at least, to the comparatively recent date of its original description by Horn (1887) which is here transcribed:

"Oblong-oval, moderately robust, fuscous to piceous, shining, clypeus slightly emarginate, somewhat concave, margin moderately reflexed, surface rather coarsely, moderately closely punctate; front similarly punctured. Thorax narrowed from the base, sides posteriorly nearly straight, anteriorly arcuate, margin entire, with short ciliæ, disk moderately convex, the punctures relatively small and sparse, the median line smooth behind, a feeble basal marginal sulcus from the hind angles. Elytra with punctures similar to those of the thorax, but indistinct, except at base and sides, at middle rugulose, sutural costa rather narrow, the discal costæ feeble, the submarginal well developed and nearly reaching the humerous. Pygidium sparsely indistinctly punctate, the punctures rather fine. Metasternum densely punctured, the hair moderately long, but dense. Abdomen sparsely indistinctly punctate, the last two segments more coarsely. Claws curved, the tooth median and strong, a little longer in the female. Maxillary palpi rather stout, the last joint fusiform, not impressed. Length .84 to .86 inch; 21.5 mm."

In the male the antennal club is not as long as the stem and in the female it is shorter than the funiculus. The abdomen of the male (Pl. V, fig. 2A) is flattened on the ventral surface and the next to the last segment bears a transverse arcuate ridge and caudad of the ridge the segment is smooth and somewhat concave. The last segment has the apex emarginate and the segment itself is

broadly concave. The posterior abdominal segments of the female (Pl. V, fig. 2B) are strongly convex, but the penultimate segment has a transverse impression near the caudal margin and the last segment is emarginate on its caudal margin. The inner spur of the hind tibia of the male is somewhat curved and bears a rather strong hook at its distal end. This hook is not present in the female and its presence on the male is a prominent and useful character which readily separates it from *P. fusca* and other closely similar species. The adult of *P. vehemens* is shown in Plate I, figure 2.

Distribution.—*P. vehemens* is probably indigenous to the Mississippi river valley. It was described by Horn (1887) from specimens collected in Kansas. Hamilton (1895) records it as rare in Pennsylvania, and Blatchley (1910) also found it rarely in Indiana. Sanders and Fracker (1916) found it scarce in Wisconsin. Forbes (1916) states that it is a typical southern species in Illinois, and Davis (1916) records it as predominating in the bottom lands of Indiana and South Dakota. The Kansas State Agricultural College collection has specimens from Mississippi and the Cornell collection has examples from Douglas county, Kan.

The data on distribution in Kansas are indefinite. Specimens have been seen from Douglas and Riley counties, and Knaus (1897) records it from Wilson county.

Relative Abundance.—Although this species is relatively abundant near Manhattan, it has not been identified with any material injury. Davis (1916) states that this species is a serious pest in the lowlands along the Missouri and Sioux rivers in South Dakota.

Among the collections at Manhattan, this species ranks eighth in relative abundance. The collections are represented by 2,001 specimens and three reared individuals, making a total of 2,004. This is 2.2 per cent of all species of *Phyllophaga* taken during this study. Practically all of the beetles were taken at lights, 33 were found on food plants, and two in the soil. As stated above, three specimens were reared from the egg.

The writer (1920) has found the life cycle of this species in Kansas to be two years. Further study shows a three-year cycle may occur and the additional data are here presented.

Soil Preferences.—The collections of this species indicate that *P. vehemens* prefers, at Manhattan, the lowlands along the Kansas

river. Blatchley (1910) says that this species occurs more commonly in damp situations and Davis (1916) finds it predominating in bottom land in Indiana and South Dakota. In this connection, it may be mentioned that an adult of this species was found under a stone lying in the water of Wildcat creek, April 23, 1920.

Attraction to Lights.—In these studies, 98.2 per cent of the total collections have been found at lights. Forbes (1916) found it more frequently near lights than in other places. The males are especially numerous, 91.5 per cent of the total being of this sex. This is one of the first species to appear at lights in the spring, having been collected as early as April 4. The flight is usually of short duration and only rarely are beetles found after July 1. The period of flight as noted for six years at Manhattan is shown in Table XVIII.

TABLE XVIII.—The period of flight of *P. vehemens*.

FLIGHT.	1916.	1917.	1919.	1920.	1921.	1922.	Av. date.
First flight	May 4	Apr. 18	Apr. 22	May 2	Apr. 4	Apr. 20	Apr. 22
Maximum flight	May 19	May 17	May 3	May 7	May 5	Apr. 22	May 7
Last flight	June 14	June 23	June 30	July 3	May 30	May 26	June 11
Period of flight	41 days	66 days	39 days	62 days	56 days	36 days	50 days

In 1918 no specimens of this beetle were found at lights. Specimens in the Kansas State Agricultural College collection indicate that flight has occurred early in previous years, having been taken April 20, 1891; April 21, 1914; and May 1, 1915. A number collected at Lawrence, Kan., were taken between April 13 and May 12. Forbes (1916) reports it as the earliest species to appear in southern Illinois where it flies from March 27 to July 1.

Food Habits.—Comparatively few individuals of *P. vehemens* have been found on food plants and the data are insufficient to show food preferences. The fact that the largest numbers were taken on willow is suggestive, since the beetles are usually abundant in bottom land. Forbes (1916) found it rare on food plants. The Kansas State Agricultural College collection contains four adults collected on plum in 1892. Table XIX shows the plants on which beetles were taken.

TABLE XIX.—The food plants of *P. vehemens* in Kansas.

PLANT.	Number of beetles.	Per cent of total.	PLANT.	Number of beetles.	Per cent of total.
Willow	9	27.2	Horse-chestnut	2	6.0
Hawthorne	6	18.1	Oak	2	6.0
Cottonwood	5	15.1	Ash	1	3.0
Spirea	4	12.1	Unidentified	1	3.0
Hackberry	3	9.0			

Proportion of Sexes.—In all collections the males have predominated and this is especially noticeable at lights where only 8.6 per cent have been females. Table XX shows the proportion of sexes of all specimens collected.

TABLE XX.—The proportion of sexes of *P. vehemens*.

SOURCE.	Total.	Females.	Males.	Per cent females.
At lights	1,889	161	1,728	8.5
On food	33	11	22	33.5
In soil	2	2	0	100.0
Reared	3	1	2	33.3

Oviposition.—Oviposition of this species has been observed from May 25 to July 2. Several cages were started to determine the number of eggs per female, but the results were unsatisfactory.

Size of Eggs.—Nine recently deposited eggs of this species were measured. They averaged 2.7 mm. in length and 1.9 mm. in width. Six of these eggs were again measured 20 days later. They were then found to average 3.6 mm. in length and 2.9 mm. in width, showing an increase in average length of 0.9 mm. and in width of 1 mm.

Length of Egg Stage.—The length of the egg stage of *P. vehemens* was found to vary from 11 to 28 days, with an average of 19.8 days for 42 eggs under observation. The first eggs to be laid have been observed as early as May 25 and the last eggs to hatch were on July 21, a period of 57 days. The data on the length of the egg stage as recorded in three different years are given in Table XXI.

TABLE XXI.—The length of the egg stage of *P. vehemens*.

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1917	2	28	19	23.5
1920	9	21	11	16.2
1921	31	26	14	20.7
	42	28	11	19.8

Length of Larval Stage.—The length of the larval stage is based on three larvæ which hatched from eggs deposited in 1917 and 1920. Two of the larvæ developed in a little over one year and the other required more than two years, which means a two-year and a three-year life cycle respectively. The first molt occurs the same year that the egg hatches, while the second molt may occur either the same year (two-year grubs) or the following year (three-year grubs). The length of the several periods of the larval stage are shown in Table XXII.

TABLE XXII.—The length of the larval stage of *P. vehemens*.

STAGE.	Number reared.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	2	47	43	45
First molt to second molt	2	314	28	171
Second molt to prepupa	2	339	66	202.5
Active larval stage	3	780	414	539
Prepupal stage	3	7	7	7
Total larval stage	3	787	421	546

The discrepancy in numbers reared, as shown in the table, is due to the fact that the molt periods were observed only on two of the three specimens. It will be noted that the average period between hatching and the first molt was 45 days, with extremes of 43 and 47 days; between the first molt and second an average of 171 days, with extremes of 28 and 314 days. The period between the second molt and the prepupal period averaged 202.5 days, with extremes of 66 and 339 days. The prepupal stage was seven days in three instances and the total larval stage varied from 431 to 787 days, with an average of 546 days.

Food of Grubs.—Although the adults of *P. vehemens* are comparatively abundant in the collections, the grub has not been found in nature and reared, and hence there was no opportunity in this study to determine the food of the grubs.

Length of Pupal Stage.—Three individuals under observation required an average of 25.3 days for the pupal stage. The maximum period was 27 days and the minimum 23 days. Pupation occurred in August. Davis (1916) gives the pupal stage for three individuals from 27 to 29 days, and records pupation from July 14 to July 20. The beetles issued during September at Manhattan. Davis found them issuing from August 7 to September 6.

Life Cycle.—Davis (loc. cit.) states that *P. vehemens* invariably has a three-year life cycle. At Manhattan it was found to have a two- and a three-year life cycle. The length of the observed life cycle is shown in Table XXIII and of the computed life cycle as calculated from the averages of the various stages is shown in Table XXIV.

TABLE XXIII.—The length of the life cycle of *P. vehemens.*

LIFE CYCLE.	Number reared.	Number of days.		
		Maximum.	Minimum.	Average.
Two-year cycle	2	477	459	468
Three-year cycle	1	838	838	838

TABLE XXIV.—The computed life cycle of *P. vehemens.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	42	28	11	19.8
Larval	3	787	421	546.0
Pupal	3	27	23	25.0
Life cycle		842	455	591.1

From Table XXIV it will be observed that the computed life cycle indicates a maximum period of development of 842 days, a minimum period of 455 days, and an average period of 591.1 days.

Phyllophaga Fusca Froelich

Description and Synonymy.—*Phyllophaga fusca* was described by Froelich in 1792 in the genus *Melolontha*. This species has been the cause of considerable confusion in the literature. It is one of the larger species, and prior to 1888 practically all of the large, dark specimens were called *fusca*. Horn (1887) recognized several races of the species and Smith (1888) divided *fusca* into four species; namely, *fusca, grandis, arcuata,* and *dubia*. The studies of Glasgow (1916) have shown that the last three are synonyms of *drakei, fervida,* and *anxia* respectively, and that *P. fervens* Gyllenhall is a true synonym of *P. fusca*.

Horn (1887) has described the species as follows:

"Form usually oblong, although somewhat variable, rufocastaneous, brown or piceous, shining. Clypeus slightly emarginate, the border moderately reflexed, surface moderately closed punctate, front usually a little more coarsely and less closely punctate. Thorax always widest at base, usually arcuately narrowed to the apex, margin entire with short cilia, surface variably punctate, never very coarsely nor very closely, usually with a smooth median line, basal channel wanting. Elytra more closely punctate than the thorax, the costæ variable, sometimes fairly distinct or again entirely obliterated, the submarginal always distinct posteriorly. Pygidium usually punctate, sometimes coarsely, sometimes more finely, always sparsely. Metasternum densely punctured, the hair long and dense, a little shorter in the female. Abdomen shining, sparsely punctate, the last two segments more coarsely. Claws curved, the tooth median, always stronger in the female. Last joint of maxillary palpi ovate, not impressed. Length .70 to .95 inch, 17.5 to 23.5 mm."

The species is quite variable in size and form and Horn believes these various forms to be geographical races. He considered the ventral abdominal characters of the males as also quite variable, but as the species was limited by Smith, the male has on the penultimate segment a transverse ventral ridge which is quite long, slightly curved and the lateral edges overlap the last segment. Near the median line the ridge is declivitous but not overhanging. (Pl. V, fig. 1A.) The female is distinguished from related species by the fact that the last ventral segment is but slightly emarginate. (Pl. V, fig. 1B.)

Distribution.—This species is widely distributed over the United States and the southern part of Canada. Horn states that it occurs as far north as the Hudson bay. It is distinctly a northern species and probably reaches its maximum in the latitude of northern Illinois. The taxonomic chaos in which this species has figured makes it difficult to determine its exact distribution from the literature.

The species as now recognized is apparently well distributed over the United States east of the Rocky Mountains. In Kansas, specimens have been seen from Douglas, Shawnee, Riley, Geary, Wilson, McPherson, and Saline counties. The Cornell collection has specimens from Ithaca, N. Y., Douglas county, Kan., Chapel Hill, N. C., and Madison, Wis.

Relative Abundance.—*P. fusca* is not an important species in the vicinity of Manhattan, Kan., being represented in the collections made during this study by 127 beetles taken at lights, seven on food plants and one reared from the egg. On the other hand, *fusca* is of great economic importance in other regions. The preponderance of this species in Illinois (Forbes, 1916) and Wisconsin (Sanders and Fracker, 1916) indicate that it is one of the most destructive species in those states. Blatchley (1910) states that it is the most abundant and injurious form in Indiana, and Moore (1914) found it predominating in Minnesota. Forbes (1894) considered it as one of the important enemies of corn, and Criddle (1911) states that the grubs are very bad in grassland.

The literature is replete with references to the importance and abundance of this species, and many of these citations are no doubt erroneous, due to the fact that it has been the common practice to call all undetermined grubs and beetles *P. fusca*. The following statement by Howard (1879) is a good illustration of the popular fallacy of referring injury by beetles or grubs to *P. fusca*. In discussing the abundance of *fusca* at Washington, D. C., he states that the grubs were very numerous in the lawns but were not doing any noticeable injury. Following a rain they were abundant on the surface of the ground and exhibited the peculiar habit of traveling on their back. From what we now know of the habits of grubs in general, it would appear that in reality he was discussing the grubs of *Cotinis nitida* Linn., known commonly as the green June beetle or fig eater.

Attraction to Lights.—This species is readily attracted to lights at Manhattan, as shown by the fact that 127 of the 135 beetles handled came from lights. Wescott (1888), Slingerland (1893), Blatchley (1910), Forbes (1916), and Sanders and Fracker (1916) in their work found the beetles numerous at lights.

Period of Flight.—The average period of flight of *P. fusca* at Manhattan was 42 days. Adults have been taken from April 22 to June 25, while the average date of the first appearance was May

5 and for the last flight June 13. Manee (1909) and Forbes (1916) give the period of activity in North Carolina and Illinois from April to July. Slingerland (1893) found the beetles coming to trap lights in New York from May 6 to July 5 in 1889, and from May 26 to June 28 in 1892.

Soil Preferences.—The data concerning the soil preferences of adults at Manhattan are very meager, only one specimen in the Kansas State Agricultural College collection giving a clue. It was found at the roots of horseradish in a garden, April 15, 1889.

Food Habits.—During these studies, seven beetles were collected on plants. Three of these were on oak, two on elm, and one each on linden and ash. The Kansas State Agricultural College collection contains specimens from plum, birch, and oak. Forbes (1916) states that *P. fusca* is rather an indiscriminate feeder. He collected 6,024 adults on 23 different plants. Poplar with 17 per cent of the total collection, willow with 16 per cent, and oak with 10 per cent were the most important species, while oak, elm, ash, walnut, apple, and hickory each represented between 5 and 10 per cent. A review of the literature shows that it has been taken on swamp oak and chestnut (Riley, 1891), burr oak (Snyder, 1897), pecan (U. S. D. A., 1908), and peach (Scott and Fiske, 1908). Davis (1916) says that the beetles prefer oak.

Proportion of Sexes.—The males of *P. fusca* are the predominating sex collected at lights as shown by Table XXV.

TABLE XXV.—The proportion of sexes of *P. fusca*.

SOURCE.	Total.	Females.	Males.	Per cent females.
Collected at lights	120	42	78	35
Collected on food plants	7	4	3	57
Reared from egg	1	1	0	100
Total	128	47	81	36

Wescott (1888) has noted that the males were much more abundant at lights than the females, representing 87.5 per cent of his collections and Slingerland (1893) found the males constituting 91 per cent of the collections at trap lights in Ithaca. Forbes (1894), in comparing light and food-plant collections, found the ratio at lights to be 2.2 males to each female and on trees 1.3 males per

female. A collection by Felt (1915) contained 133 females and 137 males.

Length of Egg Stage.—The length of the egg stage of this species was determined for 48 eggs. The earliest eggs were deposited on May 29 and the latest date on which they hatched was July 9, making a period of 41 days in which eggs were found.

The data regarding length of the egg stage are summarized in Table XXVI.

TABLE XXVI.—The length of egg stage of *P. fusca.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1917	11	19	17	18.1
1920	5	28	16	21.0
1922	32	22	17	19.8
	48	28	16	19.5

From Table XXVI it will be noted that the length of the egg stage varied from 16 to 28 days, with an average of 19.5 days for 48 eggs.

Length of Larval Stage.—The only data relative to the length of the larval stage is from one grub which hatched June 26, 1920. It molted August 9 and September 13, 1920, thus making the length of the first and second instars 44 and 36 days, respectively. It became quiescent August 12, 1921, with an active larval stage of 412 days, and pupated August 18, 1921, with a prepupal stage of 6 days, making a total larval period of 418 days. It is, therefore, apparent that this specimen had a two-year life cycle.

Food of Grubs.—The grubs of this species were not found in the field and their habits are unknown, but Criddle (1911) says they cause serious damage to grass, and Forbes (1894) has associated them with injury to corn. Felt (1912) states that they attack grass, strawberries, and corn in New York.

Description of Pupa.—The one pupa under observation was 23 mm. long and 11 mm. wide. It was creamy white when freshly transformed and just before maturing was a dark brown.

Length of Pupal Stage.—The length of the pupal stage as determined for the single individual which pupated August 18, 1921, was 27 days. Davis (1916) found the pupal stage to be 29 days.

According to Forbes (1894) pupation may occur as early as July 18, while Davis (1916) gives July 20 as the earliest date on which it may occur.

Life Cycle.—The individual which was reared in this work finished its development in 461 days, indicating that the species can go through its life cycle in two years. The collections, however, indicate that normally the life-cycle in the vicinity of Manhattan is three years, since the largest collections were made in 1917 and 1920. The collections of Forbes (1916) also indicate a three-year period in Illinois, and Davis (1916) states that *P. fusca* invariably has a three-year cycle. This point is emphasized by Devereaux (1890) who says this species was abundant in New York in 1883, 1886, and 1889, which fact checks with the big flight in Alabama in 1880, Massachusetts in 1865, and New York in 1850. The possibility of a two-year cycle is suggested by Felt (1915) who states that beetles were found two years after a large flight.

Phyllophaga Corrosa LeConte

Description and Synonymy.—This species was described by LeConte (1856) who in the same year described *P. affinis* which Glasgow (1916) has shown by a study of the genitalia to be a synonym of *P. corrosa*. The description of *P. corrosa* as given by Horn (1887) is as follows:

"Oblong-oval, slightly broader behind, form rather robust, castaneous or brown, head usually darker, moderately shining. Clypeus rather broadly emarginate, the border narrowly reflexed very closely, rather coarsely punctate, front more coarsely punctate, almost cribrate. Thorax widest at middle and very obtusely angulate, slightly narrowed to base, more obliquely in front, margin serrate, more distinctly behind the middle, sparsely ciliate, disc convex, the punctures coarse, variolate, moderately closely placed, except each side of middle where they are sparser, near the sides densely punctured, median line indistinctly smoother, a depression at the basal margin on each side. Elytral punctures moderately coarse, but not dense, surface somewhat rugulose, sutural costa distinct, first discal feeble, the others very indistinct, submarginal well developed. Pygidium rather sparsely punctate. Metasternum closely punctate, the hairs moderately long, not dense, shorter in ♀. Abdomen sparsely punctate, the last two segments more coarsely. Claws curved, with a strong median tooth rather longer in the female. Last joint of maxillary palpus fusiform and slightly flattened. Length .67 to .80 inch, 17 to 20 mm."

Distribution.—*P. corrosa* has a rather wide distribution. Horn (1887) recorded *P. affinis* from Kansas, Colorado, Oklahoma, and Texas, and Smith (1888) has added the District of Columbia and Tennessee. Both of these writers give the distribution of *P. corrosa* as Illinois, Texas, Dakota, and Minnesota.

Drury (1911) says *P. corrosa* is the most common species at lights in North Carolina. The writer has seen specimens in the Knaus collection from Nebraska, and in the University of Kansas collection are specimens collected by Snow in New Mexico.

This species probably occurs throughout Kansas. Specimens have been seen from Osborne, Mitchell, Reno, Riley, Shawnee and Douglas counties. It is distinctly local in its distribution, however, being very abundant in one locality and practically wanting in another. This is well shown by the collections of May 31, 1920, when only nine specimens were taken during several hours' collecting in one prairie situation, while in another 267 specimens were collected in a few minutes. Smith (1888) also states that it is local in the District of Columbia. Forbes (1916) found it to be strictly a southern Illinois species, and it was not taken in Wisconsin in the collections of Sanders and Fracker (1916).

Relative Abundance.—*P. corrosa,* because of its abundance in high prairies, is one of the common species at Manhattan, ranking sixth in the total collections. A total of 3,751 beetles have been secured during this study, of which 51 were collected from lights, 3,546 from food plants, 14 from soil, 118 from miscellaneous sources, 3 reared from collected grubs, and 19 reared from eggs.

Attraction to Lights.—This species is not readily attracted to lights, only 1.3 per cent of the total collections coming from this source. This is interesting in view of the fact that Drury (1911) found it the most common species at lights in North Carolina. Forbes (1916) also found it rather common at lights in southern Illinois. Several explanations may be offered for its scarcity at lights in these collections. In the first place, the high prairie, where it is most abundant at Manhattan, is some distance from any lights, the beetles become active shortly before dark, and the females rarely fly to their food.

Period of Flight.—*P. corrosa* appears moderately late, usually about the middle of May. The earliest date on which beetles have been taken is May 5, while the average date of appearance is May 21. The flight continues throughout most of June, the latest record being June 25. The average period of flight as determined for three years is 38 days. Forbes (1916) gives the flight period for southern Illinois from April 9 to July 2. Table XXVII gives the essential data on the period of flight.

TABLE XXVII.—The period of flight of *P. corrosa*.

FLIGHT.	1917.	1920.	1921.	1922.
First flight	May 17	May 5	May 25	May 17
Maximum flight	May 29	May 30	.....	.....
Last flight	June 23	June 25	June 20	.....
Period of flight	37 days	51 days	26 days	.....

Soil Preferences.—Fourteen adults have been collected in the soil and three have been reared from collected grubs. With one exception all came from uncultivated, upland soil. Ten adults and three grubs were taken at the roots of prairie grass, two adults at the roots of Jersey tea, one at the roots of cedar, and one in a corn field.

Food Plants.—Forbes (1916) states that *corrosa* is an oak-hickory-persimmon species. In Kansas it is apparently a prairie species and shows a decided preference for such low-growing plants as Jersey tea, lead plant, wild rose, and cedar. Its abundance on upland situations was closely associated with these plants. This fact is indicated in Table XXVIII which shows the food plants of this species.

TABLE XXVIII.—The food plants of *P. corrosa*.

PLANT.	Number of beetles.	Per cent of total.	Remarks.
Prairie grasses and weeds	1,583	44	Principally lead plant and Jersey.
Wild rose	690	19	
Lead plant	506	14	
Cedar	275	7	Small trees set in native prairie.
Jersey tea	198	5	
Dogwood	120	3	Edge of prairie.
Buffalo pea	55	1	
Verbena stricta	46	1	
Walnut	23	*	Small trees in native prairie.
Elm	14	*	
Oak	10	*	
Locust	8	*	
Wild mustard	8	*	
Wild grape	2	*	
Dock	2	*	
Ash	2	*	
Sumac	1	*	
Hawthorne	1	*	
Cottonwood	1	*	
Primrose	1	*	
Total	3,546	.....	

* Less than one per cent.

It is interesting to note that the females do not fly to the food plants but crawl over the ground. A total of 109 females and 9 males were taken crawling on the ground in 1920. This probably accounts for the small numbers of females on large trees and at

lights. The adults also feed on new mown hay, as was shown by a collection of 227 beetles on such food one evening in 1920.

Proportion of Sexes.—The females have predominated in all collections except those made at lights. Table XXIX shows the proportion of sexes of beetles obtained from different situations.

TABLE XXIX.—The proportions of sexes of *P. corrosa.*

SOURCE.	Total.	Females.	Males.	Per cent females.
At lights	51	8	43	15
On food plants	3,546	2,272	1,274	64
In soil	12	7	5	58
Miscellaneous	118	109	9	92
Reared from grubs	3	2	1	66
Reared from eggs	17	9	8	52

Mating and Oviposition.—Beetles were frequently taken *in coitu* during 1920. Mating begins about dusk and may occur at any time during the night. Beetles were observed mating on *Verbena stricta*, cedar, wild rose, bluestem grass, Jersey tea, and lead plant. Mating was observed as early as May 18 and as late as July 20.

In rearing cages, nine females deposited an average of 12.4 eggs, with extremes of 3 and 20 eggs. These data, however, cannot be considered conclusive. Egg laying began in the cages in 1920 on May 29 and continued until July 20.

Description of Eggs.—The egg of this species is normally like those of other species of the genus, but one egg observed when freshly laid was more spherical than others and had at one end a tiny protuberance which resembled the micropile of other insect eggs.

Length of Egg Stage.—During the years 1919 and 1920, observations were made on the length of the egg stage of 806 individuals. The data are summarized in Table XXX.

TABLE XXX.—The length of the egg stage of *P. corrosa.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1919	103	19	12	16.8
1920	703	28	11	18.2
	806	23	11	18.1

The maximum period of the egg stage is shown to be 28 days and the minimum 11 days, with an average of 18.1 days. The period of egg laying extended from June 14 to July 9 in 1919 and from May 29 to July 20 in 1920. Hatching began July 2 and ended July 28 in 1919 and extended from June 21 to August 17 in 1920.

Length of Larval Stage.—In this, as in other species, the length of the larval stage depends on whether the life cycle is two or three years. The data on this point are summarized in Table XXXI.

TABLE XXXI.—The length of the various instars of *P. corrosa*.

INSTAR.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	237	58	17	39.4
First molt to second	136	326	7	218.1
Second molt to prepupa	32	440	97	346.1
Active larval stage	35	772	379	531.8
Prepupal stage	25	15	2	6.6
Total larval stage	25	769	382	516.4

The active larval stage varied from 379 to 772 days and the prepupal stage from 2 to 15 days, while the complete larval period varied from 382 to 769 days, with an average of 516.4 days.

If we analyze the data relative to the two- and three-year grubs, as in Table XXXII, we find that the average complete larval stage for the two-year grubs was 406.5 days with extremes of 382 and 418 days, and for the three-year grubs 750.5 days with extremes of 735 and 769 days.

TABLE XXXII.—The two- and three-year larval stages of *P. corrosa*.

LIFE CYCLE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Two-year cycle	17	418	382	406.5
Three-year cycle	8	769	735	750.5

The first molt was observed to occur during the year in which the egg hatched and the second occurred the same year or the following year. In one instance, both molts took place within 38 days after hatching. Table XXXI shows that the first molt occurs from

17 to 58 days after hatching and the second molt from 7 to 326 after the first molt. The period between the second molt and the prepupal stage averaged 346.1 days with extremes of 97 to 440 days. The prepupal stage lasts from 2 to 15 days with an average of 6.6 days.

Food of Grubs.—Only three adults have been reared from collected grubs. All of these came from grass land on the native prairies near Manhattan.

Length of Pupal Stage.—The length of the pupal stage has been fairly constant during the three years that pupæ have been under observation. There has been little variation between collected material and that reared from eggs. Pupation may begin as early as July 31 and the last emergence noted was September 20. Table XXXIII shows the data on the length of the pupal stage.

TABLE XXXIII.—The length of the pupal stage of *P. corrosa*.

YEAR.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
1919	2	26	25	25.5
1921	15	26	23	24.9
1922	5	24	22	23.4
Total	22	26	22	24.6

Life Cycle.—*Phyllophaga corrosa* was found to have both a two-year and a three-year life cycle. The data on 19 individuals reared from eggs to adults are shown in Table XXXIV.

TABLE XXXIV.—The actual life cycle of *P. corrosa*.

LIFE CYCLE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Two-year cycle	16	464	429	449.3
Three-year cycle	3	791	773	782.3

It will be seen that the two-year individuals averaged 449.3 days with extremes of 429 and 464 days, while the three-year individuals averaged 782.3 days with extremes of 773 and 791 days. If we compute the average of all stages (Table XXXV) it is noted that the life cycle of two-year grubs may be as short as 415 days and the three-year cycle as much as 823 days.

TABLE XXXV.—The computed life cycle of *P. corrosa*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	806	28	11	18.1
Larva	25	769	382	516.4
Pupa	22	26	22	24.6
Total		823	415	559.1

Phyllophaga Hirticula Knoch Var. Comosa Davis

Description and Synonymy.—The synonymy of *Phyllophaga hirticula* Knoch as given by Dalla Torre (1912) is as follows:

1801 *Melolontha hirticula* Knoch, Neue. Beytr. Ins. 1, p. 79.
1817 *Melolontha hirticula* Schönherr, Syn. Ins. 1, 3, p. 173.
1842 *Phyllophaga hirticula* Harris, Rept. Ins. of Mass., 2 ed., p. 28.
1855 *Ancylonycha hirticula* Burmeister, Handb. Ent. IV. 2, p. 327.
1856 *Lachnosterna hirticula* LeConte, Jour. Acad. Nat. Sci. Phil. (2) III, p. 254.
1887 *Lachnosterna hirticula* Horn, Trans. Amer. Ent. Soc. XIV, p. 266.
1889 *Lachnosterna hirticula* Smith, Proc. U. S. Nat. Mus. XI, p. 516.

In 1916 Glasgow restored the name *Phyllophaga* proposed by Harris in 1842, and proposed *P. hirticula* as the type of the genus.

Davis (1920) noted that the specimens of *P. hirticula* collected by McColloch and Hayes in Kansas differed from the typical *hirticula* "by the absence of hairs on the elytra and the shortness or sparseness of the hairs on the thorax," and described them as a variety of *P. hirticula* which he named *comosa*. The character of the pilosity seems to be constant and the genitalia are similar to those of *P. hirticula* except that they are somewhat more robust. His description of the variety is as follows:

"Similar in shape and color to typical *P. hirticula*, being fuscoferruginous to very dark brown, moderately shining, without hairs on elytra except an occasional short one, and only a few on the head and thorax. Clypeus rather deeply emarginate, the margin narrowly reflexed, surface coarsely and densely punctate, front similarly punctate. Thorax slightly narrower at base than at middle, margin finely serrate posteriorly, coarsely so anteriorly, and with short ciliæ, surface moderately closely punctate on sides and less so on disc, the punctures more or less irregularly placed, a rather distinct channel along basal margin from the hind angles to near the middle. Elytra with smaller and

moderately closely placed punctures, somewhat rugulose at center, no rows of hairs, only an occasional short hair, and margin not fimbriate, sutural costæ distinct, submarginal ones indistinct or absent. Pygidium with punctures moderately sparse and not distinct, wider than long, the apex broadly rounded. Metasternum with fine dense punctures and densely clothed with moderately long hairs. Claws arcuate, with a strong median tooth, alike in both sexes. Length, 16.5 to 18.5 mm."

The sexes differ in the size of the antennal club, being larger in the male. The abdomen of the male (Pl. VI, fig. 1A) is depressed on the median surface. The next to the last ventral segment is more deeply depressed anteriorly, giving the impression of a ridge across the segment and the last segment is slightly concave. The abdomen of the female (Pl. VI, fig. 1B) is strongly convex and in some specimens the last segment may be faintly concave. Horn (1887) has recognized three forms of the species which he calls the "southern," "central," and "eastern" forms. All these vary in size, punctation, and pilosity.

Description.—The variety *comosa* has been noted in the literature from the vicinity of Manhattan, Kan., only;[4] from whence specimens were described by Davis. Although not specifically mentioned in his publications, Davis stated in a personal letter that this was the only region from which he had seen specimens. Specimens are in the Kansas State Agricultural College collection from Shawnee, Riley, and Geary counties, and the Knaus collection has specimens from Wilson county.

Horn (1887) gives the distribution of the typical *P. hirticula* for the entire Atlantic region extending to Nebraska and Texas, and states that it occurs abundantly. Butler (1888) found this species thick on Carolina poplar in Maryland; Kent (1890) found them likewise in the foliage of forest trees in Mississippi; Liebeck (1890) took specimens around swamp oak in New Jersey; Wickham records it from Canada (1894) and from Wisconsin (1897); Easton (1909) from Fall River, Mass.; Blatchley (1910) notes its occurrence throughout Indiana; Leng (1910) found it in northern Georgia; and Felt (1916) notes it from New York.

Relative Abundance.—This species is one of the important species in the vicinity of Manhattan, ranking ninth in the total collections. In all, 1,696 beetles have been collected, of which 1,190 were at lights, 499 from food plants, six from the soil, and one from

4. Since this was written Dawson (1924, Univ. Studies, Lincoln, Nebr., Vol. 22, p. 60) has reported this variety as occurring in Nebraska.

miscellaneous collections. Twenty-four have been reared from collected grubs and two from eggs.

Forbes (1894) places *P. hirticula* among the eight injurious species in Illinois and later (1916) states that it is the predominating species and "one of the most dangerous species in the state." Its abundance in other regions is indicated by other citations in the literature. Riley (1891) reported *P. hirticula* defoliating oak and chestnut trees by gnawing through the leaf petioles. Garman (1905) found it injuring forest trees and the grubs were abundant in bluegrass and in nurseries. Smith and Lewis (1906) record it damaging the buds and leaves of pecan, and Felt (1912) found the grubs injuring grass, strawberries, and corn. It is reported by Smith (1912) as third in importance of the May beetles in New Jersey. Felt (1916) noted it as destructive on Long Island, and Davis (1916) says *P. hirticula* was destructive in southwestern Michigan in 1914 and also in Ohio and Maryland.

Attraction to Lights.—This species is more readily attracted to lights than the preceding species (*corrosa*). Among the total of 1,722 beetles collected, 1,190, or 69 per cent of the total, came from lights. This is interesting in view of the fact that Forbes (1907) found it more abundant on trees.

Period of Flight.—The flight period of *P. hirticula* has been under observation at Manhattan for seven seasons and has varied from 10 to 88 days, with an average of 41 days. The earliest date of flight was observed in 1920 when the species was flying May 10 and the latest flight observed was August 7, 1917.

Forbes (1907) found *P. hirticula* in flight during the last days of March and later (1916) reported the flight period in central Illinois from April 28 to July 21, and in southern Illinois from April 4 to June 23. Data relating to the flight period at Manhattan are shown in Table XXXVI.

TABLE XXXVI.—The flight period of *P. hirticula* var. *comosa*.

FLIGHT.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	Average date.
First flight	May 25	May 17	May 24	May 23	May 10	June 1	May 17	May 22
Maximum flight	May 31	June 16	June 1	June 11	.....	.....	.....	June 7
Last flight	June 4	Aug. 7	June 10	June 17	Aug. 6	June 25	.....	July 2
Length of flight (days)	10	82	17	25	88	24	.....	41

Soil Preference of Adults.—Forbes (1907) noted beetles of this species flying in numbers from oats and clover fields. In the studies reported here, but six adults were taken in the soil to furnish evidence of the soil preference. Of these, two were in a corn field, two in rocky, hilly land near oak trees, one was in a garden, and one in a young orchard.

Food Habits.—*P. hirticula comosa* was found to be a rather general feeder and Forbes (1916) has found the same true in Illinois as regards *P. hirticula*. Smith (1882) found it feeding on blackberry, Roberts (1889) on pear, Riley (1891) on swamp oak and chestnut, and later (1896) on oak, Marlatt (1889) on plums and cherries in Virginia, Smith (1912) on fruit blossoms, thus causing scarring of fruit, Smith and Lewis (1906) on buds and leaves of pecan in Georgia, and Davis (1916) states that it feeds largely on hickory and oak.

In the Kansas studies, 499 adults have been found on 25 different plants and a number of undetermined grasses and weeds which are grouped under the term "miscellaneous." The more important are listed in Table XXXVII with the number of beetles found on each.

TABLE XXXVII.—The food plants of *P. hirticula* var. *comosa*.

PLANT.	Number of beetles.	Per cent of total (*a*).	PLANT.	Number of beetles.	Per cent of total (*a*).
Wild rose	103	20	Verbena stricta	4	*
Walnut	74	14	Persimmon	3	*
Oak	70	14	Hickory	3	*
Hawthorne	46	9	Coffee tree	2	*
Lead plant	43	9	Buffalo pea	2	*
Elm	32	6	Ironweed	2	*
Birch	13	2	Miscellaneous	69	13
Dogwood	12	2			
Cedar	11	2	Total	489	

(*a*) Includes 10 listed in text. * Less than one per cent.

Besides the plants listed in Table XXXVII, one beetle was taken on each of the following—plum, horse chestnut, hackberry, box-elder, locust, willow, sumac, Jersey tea, dock, and stick-tight.

In Illinois, Forbes (1916) collected 30,213 beetles on food plants, of which 43 per cent were on oak. In this work 20 per cent of 499 beetles were on wild rose. A comparison of the Kansas and Illinois collections is shown in Table XXXVIII.

TABLE XXXVIII.—A comparison of the Kansas and Illinois collections of *P. hirticula*.

Kansas.		Illinois.	
PLANT.	Per cent of total.	PLANT.	Per cent of total.
Wild rose	20.6	Oak	43.6
Walnut	14.8	Hickory	18.8
Oak	14.2	Blackberry	9.2
Miscellaneous	13.8	Elm	3.8
Hawthorne	9.2	Walnut	3.7
Lead plant	8.6	Cherry	3.3
Elm	6.4	Willow	2.9
Birch	2.6	Poplar	2.4
Dogwood	2.4	Birch	2.2
Cedar	2.2	Mountain ash	1.7
		Persimmon	1.7
		Gooseberry	1.6
		Linden	1.5
Total	94.8	Total	96.4

The remaining 3.6 per cent of the Illinois food plant collection was made up of apple, ash, boxelder, corn, hackberry, hawthorne, hazel, honey locust, plum, rose, and sycamore.

Proportion of Sexes.—The males of this species have been the more numerous at lights and the females more so on food plants. Forbes (1894) gives the proportion at lights as 4.6 males to one female and on food plants 1.3 males to one female. Smith (1888) collected 259 males and 298 females on trees in the District of Columbia. In 1907, Forbes reports the collection of 136 males and 106 females on food plants, and in New York, Felt (1916) collected 122 males and 64 females. The data on the Kansas collections are given in Table XXXIX. Sexes were not noted in all cases, so the table does not include all specimens collected.

TABLE XXXIX.—The proportion of sexes of *P. hirticula* var. *comosa*.

SOURCE.	Total.	Females.	Males.	Per cent females.
Collected at lights	1,174	293	881	24
Collected on food plants	499	273	266	54
Collected in soil	6	3	3	50
Miscellaneous collections	1	0	1	0
Reared from collected grubs	24	14	10	5
Reared from eggs	2	1	1	50
Total	1,706	584	1,122	34

Mating and Oviposition.—In 1919 two pairs were taken while mating on lead plant and in 1920 mating was noted frequently on wild rose, elm, oak, hawthorne, and walnut. The period of oviposition may occur from June 16, when first eggs were found in cages, until August 4.

Description of Eggs.—Eggs when freshly laid are about 2.5 x 1.7 mm. No fully developed eggs were measured, but one twelve days old was 3 x 2.5 mm. Forbes (1907) states that when freshly laid they are white with a glossy luster and measured 1.5 x 2 to 2 x 2.5 mm. Five days later they were swollen to 2 mm. in diameter and were 2.5 to 2.75 mm. long.

Length of Egg Stage.—The length of the egg stage was noted during three seasons for a total of 293 eggs. It was observed that 11 days was the minimum period needed for hatching and 30 days the maximum period. The average was 17.9 days. The data for the three years are shown in Table XL.

TABLE XL.—The length of the egg stage of *P. hirticula* var. *comosa*.

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1917	16	30	13	19.0
1919	42	22	14	17.5
1922	235	25	11	17.8
	293	30	11	17.9

Length of Larval Stage.—The length of the complete larval stage was obtained on only three individuals, but data on certain instars are had in larger numbers. None of the grubs reared indicate a two-year cycle, for in each case the grubs matured the third summer, indicating a three-year period. The period of the first instar averaged 35.5 days with extremes of 26 and 46. The second instar had extremes of 266 and 323 days with an average of 294 days, and the period between the second molt and the pupal stage, in only one case noted, was 412 days. Summing these we obtain an average active larval stage of 749.3 days. The prepupal stage varied from 4 to 16 days with an average of 8.7 days. If we add this to the length of the active larval stage, we have an average period for the complete larval stage of 757.7 days with extremes of 753 and 765 days. These data are shown in Table XLI.

TABLE XLI.—The length of the larval stage of *P. hirticula* var. *comosa*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	41	46	26	35.5
First to second molt	41	323	266	294.0
Second molt to prepupa	1	412	412	412.0
Active larval stage	3	754	745	749.3
Prepupal stage	25	16	4	8.7
Total larval stage	3	765	753	757.7

The first molt occurred the same year that the egg hatched and the second molt occurred during the following year between June 3 and July 6.

Food of Grubs.—The grubs of 24 specimens of *P. hirticula comosa* were reared from collections made in the field to determine the favorite food plants of the grubs. Among these, six were from alfalfa, five from oats, five from wheat, three from lawns, two each from corn and prairie grass, and one from roots of sunflower. It will be noted that they occurred most frequently in alfalfa and small grains. Only two were taken in native prairie grass, although the adults are common in such situations. It is interesting to note that none have been found in gardens. Forbes (1916) states that this species feeds on the roots of corn. Felt (1912) records grass, strawberries, and corn as food plants and Garman (1905) cites bluegrass and nurseries as haunts of the grubs.

Length of Pupal Stage.—The pupal stage of 25 specimens was found to average 27.7 days with extremes of 22 and 36 days. The total of 25 specimens includes 23 reared from collected grubs and two from eggs. The data on the two types of grubs are shown in Table XLII.

TABLE XLII.—The length of the pupal stage of *P. hirticula* var. *comosa*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared grubs	2	27	24	25.5
Collected grubs	23	36	22	27.9
	25	36	22	27.7

Life Cycle.—The data on this species point to a three-year life cycle only. Two grubs hatching in 1917 did not pupate in 1918, but died before time of pupation in 1919. Two other grubs hatching in 1919 matured in 1921, giving a life cycle of 784 days for each. Eighty-five grubs were started in cages in 1920, but none pupated in 1921 and all died in 1922. Davis (1916) states that this species invariably has a three-year life cycle and that the date of the appearance of the main brood varies in different localities. The main brood appeared in 1914 in southwestern Michigan, and in 1916 in southeastern Michigan. Forbes (1916) conjectures that their prevalence in central Illinois in 1908 and 1911 is consistent with the supposition that it has a three-year life cycle. The computed life cycle from the data at hand is summarized in Table XLIII.

TABLE XLIII.—The computed life cycle of *P. hirticula* var. *comosa*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	293	30	11	17.9
Larval	3	765	753	757.7
Pupal	25	36	22	27.7
Total		821	786	803.3

Phyllophaga Crenulata Froelich

Description and Synonymy.—*Phyllophaga crenulata* was described by Froelich in 1792 in the genus *Melolontha*. One species, *P. georgicana* Gyllenhall (1817) has been shown by Horn (1887) to be a synonym. Burmeister (1855) discussed *P. crenulata* in the genus *Ancylonycha* and LeConte (1856) placed it in *Lachnosterna* from where it was transferred to *Phyllophaga* by Glasgow (1916).

Superficially, this species resembles *P. rubiginosa* LeC. and may be easily confused with it. Horn (1887) has separated the two on the basis of a feebly or strongly crenate margin of the thorax. The abdomen of the male (Pl. VI, fig. 2A) is not flattened but the penultimate segment may be slightly concave. The abdominal segments of the female (Pl. VI, fig. 2B) are strongly convex and look much like the segments of the male. The genitalia (Pl. IX, fig. 3) are the most reliable characters to separate this species from its allies.

There is to be found some variation in the character of the pubescence of the elytra and Horn (1887) has noted that those specimens

in which the hairs are more conspicuous are females. Horn gives the following description of the species:

"Oblong, very little wider posteriorly, brown, feebly shining, surface clothed with short yellowish recumbent hairs, often with erect hairs intermixed. Clypeus emarginate, the border reflexed, surface coarsely and closely punctate with short erect hairs, front more densely punctured with longer hairs. Thorax with lateral margin coarsely serrate, the median smooth line interrupted, surface very coarsely and closely punctate, less densely at sides and base, with moderately long erect yellowish hairs. Elytra equally punctured, the punctures much finer than on the thorax, moderately closely placed, sutural costa feeble, discal costæ usually indistinct, submarginal costa well marked and entire, surface with short recumbent pubescence, often with erect hairs intermixed. Pygidium with coarse moderately dense punctures and short erect hair. Metasternum moderately closely punctured at the sides, smoother at middle, the hair rather long but sparse. Abdomen less densely but more coarsely punctured and with short sparse pubescence. Claws with a strong median tooth, alike in both sexes. Length, .65-.80 inch; 17-20 mm."

Distribution.—*P. crenulata* is a species of wide distribution, being most numerous east of the Mississippi and south of the Ohio rivers. Horn (1887) states that it occurs in the region bounded by Massachusetts and South Carolina, Kansas and Indian Territory [Oklahoma]. Smith (1888) had specimens from New York, New Jersey, Texas, Iowa, Missouri, Illinois, Alabama, Tennessee, and noted that Ulke had specimens from Florida, Nebraska, and Dakota. He also collected it in Kentucky and Michigan. Blatchley (1910) records it from Indiana, and Forbes (1916) found it general in Illinois, but most abundant in the southern part. The collections of Sanders and Fracker (1916) show it to be rare in Wisconsin. The Cornell collection has specimens from Ithaca, N. Y., and Douglas county, Kansas.

The distribution in Kansas is apparently limited to the eastern half of the state. Popenoe (1877) records it from eastern Kansas and Knaus (1897) says that it is not common in Wilson, Douglas, Riley and Saline counties. The writer has seen specimens from Riley, Wyandotte, and Douglas counties.

Relative Abundance.—This species is comparatively rare in the vicinity of Manhattan, Kan. Sixty-eight specimens were collected at lights, 57 from food plants, and two from the soil. One adult was reared from a collected grub and one from the egg. It is evident that the species is not of any great economic importance.

Attraction to Lights. The few collections made at Manhattan indicate that *P. crenulata* is not strongly attracted to lights. It

has frequently been collected on food plants considerably in advance of its appearance at lights, and in those years when collections were made from both sources they were more abundant on plants. A total of 52 per cent of all collections were made at lights.

Period of Flight.—In the vicinity of Manhattan, *P. crenulata* is one of the moderately late-flying species. The earliest date on which it has been taken is May 28 and the latest date September 3. The average period of flight is about two months. Specimens in the Kansas State Agricultural College collection taken May 9, 1892, indicate that it may appear much earlier. Forbes (1916) gives the period of flight in Illinois from May 12 to August 6.

Table XLIV shows the period of flight at Manhattan during the years of these observations.

TABLE XLIV.—The period of flight of *P. crenulata.*

FLIGHT.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	Average date.
First flight	June 2	June 18	June 3	May 28	June 15	May 31	June 10	June 6
Maximum flight	July 5	June 28	June 11	.....	June 26	.....	June 16	June 23
Last flight	July 8	Sept. 3	Aug. 5	.....	Aug. 30	July 20	July 18	Aug. 4
Length of flight (days)	36	77	63	.....	76	51	38	57

Soil Preference of Adults.—The data in this study are not sufficient to draw conclusions on the soil preferences of the adults. One adult was found in a lawn and one adult and a grub were collected in a cornfield.

Food Habits.—Although the collections from food plants have not been large, they represent 16 different host plants. Linden was apparently the preferred food, followed by horse chestnut and birch. The principal food plants are shown in Table XLV.

TABLE XLV.—The food plants of *P. crenulata.*

PLANT.	Number collected.	Per cent of total.	PLANT.	Number collected.	Per cent of total.
Linden	15	26.3	Locust	3	5.2
Horse chestnut	7	12.2	Hawthorn	3	5.2
Birch	7	12.2	Cherry	3	5.2
Strawberry	5	8.7	Dogwood	3	5.2
			Miscellaneous	83	19.8

In all, 129 beetles were taken on food plants. Those cited in Table XLV constitute about 36 per cent of the total and the remainder is represented by one or more specimens from the following: Willow, plum, Virginia creeper, elm, boxelder, Norway maple, hackberry, and walnut. The Kansas State Agricultural College collection contains one specimen found feeding on plum in 1892.

Forbes (1916) found persimmon to be the preferred host in Illinois, followed by willow, hickory, and poison ivy. He also collected small numbers from elm, grape, hackberry, and oak. Smith (1882 and 1888) reports *P. crenulata* common on blackberry and roses. Townsend (1893) describes the adults swarming in the foliage of red oak in Michigan.

Proportion of Sexes.—In the collections during this study, the males have predominated at lights and the females on trees. Table XLVI shows the proportion of sexes for the different collections.

TABLE XLVI.—The proportion of sexes of *P. crenulata.*

SOURCE.	Total.	Females.	Males.	Per cent females.
Collected at lights	61	10	51	16
Collected on food	57	30	27	52
Collected in soil	2	1	1	50
Reared from grubs	1	1	0	100
Reared from eggs	1	1	0	100
Total	122	43	79	35

Description of Eggs.—The egg of *P. crenulata,* like other May beetle eggs, is pearly-white when freshly laid and oblong oval in shape. As development proceeds it becomes creamy-yellow and more nearly spherical in shape. The eggs were not measured in this work, but Forbes (1907) gives 1.5 to 2.5 mm. as their size. He does not state whether this is at the beginning or near the end of their period of development. Oviposition was found to occur in July at Manhattan.

Length of Egg Stage.—The length of the egg stage observed in 1920 and 1922 was found to average 18.2 days for 24 eggs. The maximum length of the stage was 20 days and the minimum period was 14 days. The pertinent data are shown in Table XLVII.

TABLE XLVII.—The length of the egg stage of *P. crenulata*.

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1920	19	20	14	18.3
1922	5	19	14	17.6
	24	20	14	18.2

Length of Larval Stage.—One individual of *P. crenulata* was reared from the egg to pupa in 385 days, while the length of the first instar was determined in seven instances, and the prepupal stage in two cases. The length of these and the other stages is shown in Table XLVIII.

TABLE XLVIII.—The length of the larval stage of *P. crenulata*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	7	54	35	44
First to second molt	1	284	284	284
Second molt to prepupa	1	59	59	59
Active larval stage	1	378	378	378
Prepupal stage	2	8	7	7.5
Complete larval stage	1	385	385	385

Besides the one larva reared, another which hatched August 3, 1920, and died August 27, 1921, from its size indicated the possibility of a three-year cycle as well as the two-year cycle observed.

Food of Grubs.—One grub collected in a cornfield and reared to maturity is the only record in these studies of the food habits of the grubs of this species.

Description of Pupa.—The pupa of this species is creamy-white when freshly transformed. It gradually darkens during development. One pupa which was measured was 20.5 mm. long and 10 mm. in width.

Length of Pupal Stage.—The length of the pupal stage was determined in only one instance and was found to be 21 days. Pupation occurred August 22. Another grub pupated August 28, but failed to mature. Davis (1916) found the pupal stage of this

species to vary from 23 to 26 days with an average of 24.7 days. In his studies, pupation took place from July 18 to August 6, and transformation to the adult between August 13 and August 30. It is interesting to note that Riley (1891) thought this species must mature in the spring, since it appeared later in the season than the common species.

Life Cycle.—The life cycle was determined for a single female specimen which hatched from an egg laid July 15, 1920, and matured September 12, 1921, a period of 424 days, indicating a two-year period from oviposition to oviposition. Davis (1916) found this species to have a three-year cycle and in one case an indication of a four-year cycle. The yearly collections in this work, and the collections of Forbes, give no clue to the length of life.

Phyllophaga Affabilis Horn

Description and Synonymy.—This species has not been involved in complicated synonymical changes having been described as *Lachnosterna affabilis* by Horn in 1887, and the only change has been in the generic name from *Lachnosterna* to *Phyllophaga*. The sexes differ in the size of the antennal club and the abdominal segments. The abdominal segments of the male (Plate VI, fig. 3A) are flattened and the last segment has a slight concavity, while in the female (Plate VI, fig. 3B) the segments are strongly convex. The original description by Horn (1887) follows:

"Oblong, subcylindrical, rufotestaceous, surface shining. Head moderately broad, darker in color. Clypeus feebly but distinctly emarginate, margin moderately reflexed, punctures moderately coarse not close, front more finely and closely punctate. Thorax short, sides regularly arcuate, margin entire, not ciliate, punctation moderately coarse, regularly placed, not close, smoother near the sides. Elytra with punctures as coarse and close as on the thorax, the surface somewhat scabrous also, the costæ faintly indicated. Pygidium coarsely sparsely punctate. Metasternum sparsely coarsely punctate, the hair short and sparse. Abdomen sparsely punctate at the sides, smoother at middle, not hairy. Last joint of palpi fusiform, slightly impressed. Claws feebly curved, the tooth small and very near the base in the male. Length, .61 inch; 15 mm."

Distribution.—This species is apparently of limited distribution. It was originally described from Kansas, and so far as the writer is able to learn has not been found elsewhere. All the specimens mentioned herein are from Riley county, while the Knaus collection has specimens from Douglas county.

Relative Abundance.—*P. affabilis* is one of the rarer species in the area in which it occurs, being represented by only 49 specimens in the collections at Manhattan. Four were reared from eggs, one from a collected grub, and 44 were taken at lights. It is, therefore, plainly evident that the species is relatively of little importance. The species ranks 19th in relative numbers.

Attraction to Lights.—Of the 49 beetles under consideration, 44, or approximately 89 per cent, were taken at lights.

Period of Flight.—The limited data on the flight period show that *P. affabilis* is one of the late-flying May beetles. It is present at lights during July and August. The earliest flight noted was July 5, 1921, and the latest flight observed was August 13, 1917.

Soil Preference of Adults.—Here again the data are meager. One adult was reared from a grub collected in an alfalfa field.

Food Habits.—No beetles of this species were found on food plants.

Proportion of Sexes.—The data relating to the proportion of sexes are shown in Table XLIX. From the small numbers of beetles collected, it would seem that the females are strongly attracted to lights, although outnumbered by the males.

TABLE XLIX.—The proportion of sexes of *P. affabilis*.

SOURCE.	Total.	Females.	Males.	Per cent females.
Collected at lights	44	18	26	40
Reared from collected grubs	1	0	1	0
Reared from eggs	4	2	2	50
Total	49	20	29	40

Mating and Oviposition.—Mating of this species has not been noted. The period of egg laying as determined in 1921 extends from July 21 to August 5.

Description of Eggs.—When deposited, the eggs are elongate oval and from 2 to 2.5 mm. in length and 1 to 1.5 mm. in width. As development progresses they enlarge and assume the nearly spherical shape as do the eggs of other species.

Length of Egg Stage.—The length of the egg stage was determined for 54 eggs. The average period of development was 14.3

days, with a maximum of 16 days and a minimum of 10 days. The first egg laid was July 21 and the first eggs hatched on August 2, the period of hatching extending to August 17. The data on the length of the egg stages in 1921 and 1922 are given in Table L.

TABLE L.—The length of the egg stage of *P. affabilis.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1921	49	16	12	14.6
1922	5	13	10	11.4
	54	16	10	14.3

Description of Larva.—The newly hatched larva is about 6 mm. long or 3.5 mm. when lying in its usual coiled position. The width of the head at this time is 1.2 mm.

Length of Larval Stage.—The length of the complete larval stage was determined in five instances and found to average 347 days with extremes of 338 and 361 days. The data on the various stages are shown in Table LI.

TABLE LI.—The length of the larval stage of *P. affabilis.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	33	44	23	28
First to second molt	19	304	33	198.8
Second molt to prepupa	5	292	35	228
Active larval stage	5	357	334	342.8
Prepupal stage	5	5	4	4.2
Total larval stage	5	361	338	347

The table shows there is a great variation in the period from the first to the second molt and likewise from the second molt to the prepupa. This is due to the fact that about 35 per cent of the larvæ molted twice during the summer in which they hatched, and the remainder postponed the second molt until the second season. The length of the active larval stage averaged 342.8 days, with extremes of 334 and 357 days. The prepupal stage for five individuals was fairly constant, varying from four to five days.

Food of Grubs.—The only record of the food of grubs was in the rearing of a beetle from a grub collected in an alfalfa field.

Length of Pupal Stage.—The length of the pupal stage was determined in five instances and was found to vary from 14 to 16 days, with an average of 14.6 days. Pupation occurs early in the summer (July 10 to August 7) and it is possible that the adults fly the same year.

Life Cycle.—Four individuals were reared from egg to adult and the life cycle averaged 376.6 days with extremes of 369 and 389 days. If the beetles fly soon after maturing from the pupa, the life cycle from oviposition to oviposition is slightly over one year. If, however, the beetles do not emerge until the following summer, the life cycle will occupy approximately two years. The point as to the length of time the adult stays in the soil after maturing has yet to be determined. When the lengths of the various stages are considered (Table LII), the average length of the life cycle is found to be 375.9 days.

TABLE LII.—The computed life cycle of *P. affabilis*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg stage	54	16	10	14.3
Larval stage	5	361	338	347.0
Pupal stage	5	16	14	14.6
Length of life-cycle		393	362	375.9

Phyllophaga Tristis Fabricius

Description and Synonymy.—*Phyllophaga tristis* was originally described in the genus *Melolontha* by Fabricius (1781). In 1891 Knoch described the same species as *Melolontha pilosicollis*. Erichson (1848) discusses *pilosicollis* in the genus *Trichestes* and Burmeister (1885) considered *tristis* in the genus *Ancylonycha*. The following year LeConte (1856) placed *tristis* in the genus *Lachnosterna* where it remained until Glasgow (1916) restored the name *Phyllophaga* proposed by Harris.

The original description (Fabricius, 1781) is here given for its historical value.

"M. thorace villoso obscuro, elytris laenibus testaceis, scutello albido.

"Habitat in America boreali. Dom. Blakburn. Affinis M. testaceæ. Caput et thorax obscura, hirta. Scutellum rotundatum hirsutie densa albidum. Elytra laenia, testacea, Corpus obscurum."

A better and more complete description is given by Horn (1887). It follows:

"Oblong-elongate, slightly broader behind, sometimes slightly oval, yellowish testaceous, sometimes slightly reddish, sparsely clothed with short semierect hair on the elytra, with longer erect hair on the thorax and at base of elytra. Clypeus entire, concave, coarsely sparsely punctured, not prolonged at sides on the eyes, front more densely punctured and with erect hair, not long. Thoracic margin entire, fimbriate with long hair, disc coarsely and rather closely punctured, hair long, erect and yellow. Elytra evenly punctured, the punctures closer than on the thorax, but not dense, pubescence sparse, short, semierect, with longer hairs at the base, extending somewhat along the suture, discal and submarginal costæ entirely obliterated. Pygidium coarsely and closely punctured with moderately long erect hairs. Metasternum densely finely punctured, the hair long, yellow and silken. Abdomen coarsely, usually moderately closely punctate, shining, the pubescence very short. Last joint of maxillary palpi short, ovate, slightly impressed. Claws slightly curved, the tooth acute, moderate in size and median ♀ or smaller and intramedian ♂. Length .45-.60 inch; 11.5-15 mm."

The adult is shown in Plate I, figure 3.

The female genitalia of this species are shown in Plate IX, figure 2. The sexes differ on the ventral abdominal segments. In the male (Pl. VII, fig. 1A) they are flattened on the median line, but next to the last segment has a short, transverse ridge near the cephalic border and the last segment has the cephalic margin somewhat elevated and prolonged posteriorly at the middle. The segments of the female (Pl. VII, fig. 1B) are strongly convex. The tarsal claws exhibit no sexual differences as they do in some species, but the size of the antennal club is larger in the male than in the female.

Distribution.—*Phyllophaga tristis* has a wide distribution and is apparently present wherever oaks occur. Horn (1887) states that this species probably has the widest range of any in our fauna. He had observed specimens "from the entire region east of the Rocky mountains and from Oregon and Washington Territory." Wickham (1894) records it from Canada and the Kansas State Agricultural College collection has specimens from New Mexico. The Cornell collection has specimens from Douglas county, Kansas; Chapel Hill, N. C.; Marliboro, N. Y.; and Elmhurst, Long Island.

Forbes (1916) found this species to be limited in its local distribution and thinks that distribution is influenced by ecological con-

ditions other than latitude and food. Sanders and Fracker (1916) obtained small numbers at only two places in Wisconsin, while Snyder (1897) says it is abundant some years.

The distribution in Kansas, as determined from specimens examined, includes Ottawa, Riley, Pottawatomie, Shawnee, Douglas, Marion, Cowley, and Chautauqua counties.

Relative Abundance.—This species has been rare in the collections made during this study and ranks 17th among 25 species in the area considered. Only one specimen was taken at lights from 1916 to 1922, while 67 were found on food plants and 46 in the soil. One adult was reared from a collected grub and four from eggs, making a total of only 119 individuals. Apparently this species is not sufficiently abundant in Kansas to be of great economic importance. Davis (1916) regards it as one of the least important species. In years of abundance, because of its close association with oaks, it may be injurious to those trees. The grubs may be pests of wheat, as indicated by the receipt of a large number of beetles taken on wheat heads at Peabody, Kan., in 1913, with the statement that the beetles were emerging in large numbers. Forbes (1907) considered it one of the eight injurious species of Illinois, and Snyder (1897) says the grubs often ruin timothy fields in Wisconsin. Felt (1916) records it as one of the most destructive species on Long Island.

Attraction to Lights.—Only one specimen was taken at lights during seven years collecting. Forbes (1916) states that it appears only occasionally. This may help to explain why Sanders and Fracker (1916) took so few specimens at lights in Wisconsin, while Snyder (1897) records it abundant enough to ruin timothy fields. This species may fly shortly before dark. Manee (1909) reports them flying from 6 to 8 p. m. in North Carolina. Linton (1888) describes a big flight at Barrows, Ind., May 7, 1887, which began just after sundown and continued until after dark.

Period of Flight.—The data on the period of flight in Kansas are limited to the food plant collections of 1920, when beetles were taken from May 11 to June 4, the maximum numbers being present May 19. Davis (1916) states that *tristis* is one of the first species to appear in the spring and the flight is usually over by June 1. Forbes (1916) found the period of flight to be from March 28 to June 21 in southern Illinois, May 2 to July 2 in central Illinois, and May 16 to July 2 in northern Illinois. Blatchley (1910) gives April 8 to June 9 as the flight period in Indiana. Specimens in the Kansas State Agricultural College collection from Louisiana show that they were flying in that state as early as March 22.

Soil Preferences of Adults.—From the data obtained in these studies, *P. tristis* apparently prefers rock covered, sloping soils. Practically all of the 46 specimens found in the soil came from such situations. In many cases the adults were around the roots of sumac and oak and others under small stones. Adults were also found under stones in two localities in southern Kansas. One adult was found in the soil of a garden.

Food Habits.—*P. tristis* is predominantly an oak species throughout its range. In the present studies, 67 specimens were collected on plants, 66 of which were taken on oak and one on willow. The Kansas State Agricultural College collection contains specimens collected in 1889 on willow and Jersey tea. A number of beetles were received from Peabody, Kan., in 1913, where they were said to be feeding on the heads of growing wheat.

Smith (1888) took this species on pear and oak in the District of Columbia, and Townsend (1893) reported the beetles swarming on red oak in Michigan. Manee (1909) also found the beetles flying to gummy oak buds in North Carolina. Davis (1916) lists it as an oak-hickory species. Forbes (1916) collected 1,744 specimens on plants, 93.7 per cent of which were from oak and 2.6 per cent from hickory. The remaining 3.7 per cent came from apple, locust, poplar, walnut, and willow. Scott and Fiske (1902) record the beetles as common on peach and plum trees in Georgia, and Marlatt (1889) found them associated with injury to plums and cherries in Virginia.

Proportion of Sexes. — In the various collections during this study, the females have predominated at lights. Felt (1915) records a collection of 115 beetles, 90 of which were females. Table LIII shows the proportion of sexes in all but the light collection. The one beetle taken at lights was not noted as to sex, but was probably a male.

TABLE LIII.—The proportion of sexes of *P. tristis*.

SOURCE.	Total.	Females.	Males.	Per cent females.
Collected on food plants	67	39	28	58
Collected in soil	46	24	22	52
Reared from grubs	1	0	1	0
Reared from egg	4	2	2	50
Total	118	65	53	55

Mating and Oviposition.—Mating of *P. tristis* was observed several times during May, 1920, on oak. The process was similar to that of other species. Smith (1888) states that this species is the most common one to be found mating. Oviposition occurs in the soil during May and early June. In rearing cages, nine females deposited 120 eggs or an average of 13.3 eggs per female, with extremes of 4 and 30 eggs.

Description of Eggs.—The eggs of this species, like the others, are pearly white and when freshly laid are elongate oval in shape and about 1.5 mm. long by 1 mm. wide. As development proceeds they become more globular and reach a length of about 3 mm. and a width of from 2 to 2.5 mm.

Length of Egg Stage.—The length of the egg stage was determined in 1920 for 306 eggs. The average period of development was 17.2 days, the maximum period being 23 days and the minimum period 10 days.

Description of Larva.—The larvæ of *P. tristis* when freshly hatched are 4 to 4.5 mm. long and 1 mm. wide at the head.

Length of Larval Stage.—The length of the complete larval stage was determined for six individuals. It was found to vary from 115 to 443 days with an average of 374.6 days. One larva was observed to complete its growth the same season and pupate. In this instance, 115 days were required for the complete larval stage, but the length of the active larval and prepupal stages were not noted and hence are not included in the summaries of Table LIV which gives the pertinent data on the various stages as observed in this study.

TABLE LIV.—The length of the larval stage of *P. tristis*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	22	52	22	33.9
First to second molt	22	28	10	18.0
Second molt to prepupa	4	372	361	364.7
Active larval stage	4	426	413	420.7
Prepupal stage	3	7	5	6
Complete larval stage	6	433	115	374.6

It will be noted that both molts occur the same season in which the egg hatches. The average period of the first instar was 33.9 days with extremes of 22 and 52 days. The second molt varied from 10 to 28 days after the first molt and the average period was 18 days. If we combine the two averages we find that both molts will be completed on an average of 51.9 days after hatching. The longest period is between the second molt and the time when the prepupal condition is assumed. This stage averaged 420.7 days, but does not include the record of the one individual which completed its entire larval growth in 115 days.

The prepupal stage was noted for only three specimens and was found to average 6 days with extremes of 5 and 7 days. From these data it is evident that the grubs may have a one- or a two-year life cycle.

Food of Grubs.—The only record of the food of the grubs is that given in the literature by Snyder (1897) in which he notes the grubs feeding on the roots of timothy in Wisconsin.

Description of Pupa.—The pupæ of this genus resemble those of other species but are smaller, being about 13 mm. long and 7 mm. across the thorax. They are creamy white when freshly transformed, gradually darkening to a brownish yellow on all parts of the body except the abdomen, which is of a pale yellow color.

Length of Pupal Stage.—The length of the pupal stage was determined in five instances and was found to vary from 17 to 28 days with an average of 21.4 days. Pupation may occur as early as August 9.

Life Cycle.—Four individuals were reared from egg to adult. Three of these had a two-year life cycle and one had a one-year period. The average period of development of the two-year beetles was 461 days with extremes of 451 and 474 days. The one-year example completed its development in 137 days. The data on the one- and two-year periods of development are summarized in Table LV.

TABLE LV.—The life cycle of *P. tristis*.

LIFE CYCLE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
One-year cycle	1	137	137	137
Two-year cycle	3	474	451	461
	4	474	137	380

Davis (1913) records this species as having a two-year life cycle. If we take the averages of the various stages as here presented, we get a computed average life cycle of 413.2 days with a minimum period of 142 days and a maximum period of 484 days. These data are presented in Table LVI.

TABLE LVI.—The computed life cycle of *P. tristis*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg stage	306	25	10	17.2
Larval stage	6	433	115	374.6
Pupal stage	5	28	17	21.4
Life cycle		484	142	413.2

Summary of Melolonthinæ

The study of the life cycle in the subfamily *Melolonthinæ* has been confined to the genus *Phyllophaga* Harris. During the period 1916 to 1922, inclusive, an intensive study was made of the species of the genus occurring in the vicinity of Manhattan. Two lines of investigation have been followed in this work, the systematic collection of adults and larvæ, and the determination of the length of the life cycle of the various species encountered. It will be observed that of the 97 species of *Phyllophaga* that have been reported in the United States, 25 have been found in the vicinity of Manhattan. The length of the life cycle has been determined for 17 species. Ten of these are treated in the present discussion and seven have been discussed in previous publications. Six have not been studied elsewhere and little information is available for several others.

During the seven years of this investigation, 91,490 specimens of the 25 species were collected. These varied in numbers from 31,966 specimens of *P. crassissima* Blanch. to one each of *P. inepta* Horn and *P. gracilis* Burm. Table LVII summarizes the relative abundance of all species studied at Manhattan.

TABLE LVII.—The relative abundance of all species of *Phyllophaga* at Manhattan.

SPECIES.	Number collected.	Per cent of total.
Crassissima	31,966	34.9
Lanceolata	15,851	17.3
Rubiginosa	15,130	16.5
Futilis	10,362	11.3
Rugosa	4,010	4.4
Corrosa	3,732	4.1
Bipartita	3,523	3.9
Vehemens	2,001	2.2
Hirticula	1,696	1.8
Implicita	982	1.1
Longitarsa	909	0.9
Glabricula	440	0.5
Congrua	135	0.1
Fusca	135	0.1
Crenulata	127	0.1
Prætermissa	115	0.1
Tristis	114	0.1
Submucida	57	0.06
Affabilis	44	0.04
Fervida	41	0.04
Inversa	33	0.03
Ephilida	16	0.02
Ilicis	9	0.01
Inepta	1	0.01
Gracilis	1	0.01

The adults of 24 species here treated are nocturnal in flight habits. One species, *P. lanceolata,* occurring in the vicinity is diurnal. Flight begins about dusk with the nocturnal fliers and may continue until dawn. The earliest and latest date of flight, as noted, and the period of flight of all species studied are summarized in Table LVIII.

The period of flight in the vicinity of Manhattan for the genus as a whole may begin as early as April 4, and may continue until the first week in September. The maximum flight for most species is in May or early June. The length of the flight season varies considerably with the different species, but in general the earlier appearing species have the longer flight period.

The proportion of sexes of all species collected shows that the males greatly predominate at lights, while the females are slightly more numerous in all other collections. The proportion of sexes of all species collected at Manhattan are summarized in Table LIX.

TABLE LVIII.—The period of flight of all species of *Phyllophaga* at Manhattan.

SPECIES.	Average flight period.				Possible flight period.		
	Average date first flight.	Average date maximum flight.	Average date last flight.	Average period of flight (days).	Earliest collection.	Last collection.	Possible flight period (days).
Vehemens	April 22	May 7	June 11	50	April 4	July 3	90
Futilis	April 24	May 11	June 23	60	April 12	July 22	101
Rubiginosa	April 26	May 16	June 24	59	April 18	Aug. 9	113
Crassissima	April 30	May 24	July 8	70	April 22	Aug. 17	117
Rugosa	May 3	(a)	July 2	60	April 23	July 19	87
Fusca	May 5	May 13	June 13	82	April 22	June 25	64
Implicita	May 11	May 28	June 19	40	April 24	July 21	88
Corrosa	May 13	May 30	June 23	41	May 5	June 25	51
Bipartita	May 14	May 27	June 22	39	May 5	July 24	80
Congrua	May 15	May 26	June 9	26	May 10	June 10	31
Hirticula var. comosa	May 22	June 7	July 2	41	May 10	Aug. 7	89
Inversa	May 23	June 1	June 15	23	May 21	June 17	27
Fervida	May 17	(a)	June 18	32	May 5	June 23	49
Prætermissa	May 26	(a)	June 7	12	May 16	June 12	27
Crenulata	June 6	June 23	Aug. 4	54	May 28	Sept. 3	98
Lanceolata	June 15	June 25	July 25	40	June 11	July 30	49
Longitarsa	June 26	July 14	Aug. 13	48	June 18	Sept. 2	76
Submucida	July 2	July 14	Mar. 18	47	June 30	Sept. 1	64
Ephilida	July 4	(a)	July 25	21	June 29	Aug. 2	34
Glabricula	July 7	July 15	Aug. 20	44	June 18	Sept. 6	80
Affabilis	July 20	(a)	Aug. 4	15	July 5	Aug. 13	39

(a) Data insufficient.

TABLE LIX.—The proportion of sexes of all species of *Phyllophaga* observed.

SPECIES.	Light collections.			Food plant collections.			Soil and miscellaneous collections.			Reared from grubs.			Reared from egg.		
	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.
Crassissima	7,128	19,788	26,916	634	769	1,403	103	134	327	185	188	373	40	41	81
Lanceolata	0	0	0	8,737	7,108	15,845	3	3	6	20	15	35	8	15	23
Rubiginosa	1,021	1,979	3,000	6,299	5,530	11,829	73	118	191	63	66	129	14	15	29
Futilis	549	6,954	7,503	678	976	1,654	8	5	13	3	3	6	7	9	16
Rugosa	734	1,523	2,257	494	591	1,085	46	49	95	53	62	115	9	11	20
Corrosa	8	43	51	2,272	1,274	3,546	116	14	130	2	1	3	9	8	17
Bipartita	60	2,599	2,659	317	515	832	24	19	43	4	0	4	1	2	3
Vehemens	161	1,728	1,889	11	22	33	2	0	2	0	0	0	1	2	3
Hirticula var. comosa	293	881	1,174	273	226	499	3	4	7	14	10	24	1	1	2
Implicita	75	7	82	600	28	628	8	1	9	64	3	67	19	3	22
Longitarsa	573	327	900	0	1	1	2	2	4	2	1	3	29	19	48
Glabricula	1	422	423	0	11	11	3	4	7	2	0	2	0	0	0
Congrua	0	129	129	0	6	6	0	0	0	0	0	0	0	0	0
Fusca	42	78	120	4	3	7	0	0	0	0	0	0	1	0	1
Prætermissa	66	27	93	9	9	18	2	2	4	5	7	12	1	1	2
Tristis	0	0	0	39	28	67	24	22	46	0	1	1	2	2	4
Crenulata	10	51	61	30	27	57	1	1	2	1	0	1	1	0	1
Fervida	2	37	39	2	0	2	0	0	0	0	0	0	0	0	0
Submucida	6	35	41	1	2	3	2	0	2	9	11	20	0	0	0
Inversa	0	17	17	0	15	15	1	0	1	0	0	0	0	0	0
Ilicis	0	2	2	2	4	6	0	1	1	0	0	0	0	0	0
Affabilis	18	26	44	0	0	0	0	0	0	0	1	1	2	2	4
Ephilida	4	12	16	0	0	0	0	0	0	0	0	0	0	0	0
Gracilis	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Inepta	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Total	10,751	36,666	47,417	20,402	17,146	37,548	421	379	800	427	369	796	145	131	276
Per cent of total	22.6	77.4	100.0	54.3	45.7	100.0	52.6	47.4	100.0	53.6	46.4	100.0	52.5	47.5	100.0

The data on the length of the egg stage of all species observed are summarized in Table LX. It will be seen that the shortest period of development was seven days in the case of *P. longitarsa* and the longest period with *P. implicata,* which was 31 days.

TABLE LX.—The length of the egg stage of all species of *Phyllophaga* observed.

SPECIES.	Number of eggs hatching.	Number of days.		
		Maximum.	Minimum.	Average.
Affabilis	54	16	10	14.3
Bipartita	262	24	11	16.6
Corrosa	806	28	11	18.1
Submucida (*a*)	84	20	13	14.0
Vehemens	42	28	11	19.8
Tristis	306	23	10	17.2
Fusca	48	28	16	19.5
Crenulata	24	20	14	18.2
Longitarsa	447	19	7	12.7
Prætermissa	185	23	12	17.6
Ephilida	3	15	12	13.0
Rugosa	127	29	14	19.5
Rubiginosa	180	24	11	17.0
Lanceolata	1,808	29	10	15.8
Futilis	1,017	38	11	21.1
Crassissima	1,000	27	8	16.1
Hirticula var. comosa	293	30	11	17.9
Implicita	190	31	10	18.2

(*a*) Eggs collected in field shortly after deposition.

The data on the active larval stage, by which is meant the period from hatching until the time the prepupal condition is assumed, are summarized for all species observed in Table LXI. In this table it will be noted that the period varies from 298 to 823 days. The one instance of *P. tristis* maturing the same season as hatching is not considered in the table because the time when it became quiescent was overlooked and not noted, chiefly because of the unexpected shortness of the period.

TABLE LXI.—The length of the active larval stage of all species of *Phyllophaga* observed.

SPECIES.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Affabilis	5	357	334	342.8
Bipartita	9	781	405	683.0
Corrosa	35	772	379	531.8
Submucida	13	687	658	668.8
Vehemens	3	780	414	539.0
Tristis	4	426	413	420.7
Fusca	1	412	412	412.0
Crenulata	1	378	378	378.0
Longitarsa	67	691	298	340.0
Prætermissa	5	772	390	692.0
Rugosa	22	778	399	678.7
Rubiginosa	47	798	397	737.2
Lanceolata	32	685	335	648.8
Futilis	19	773	389	427.5
Crassissima	116	823	405	533.8
Hirticula var. comosa	3	754	745	749.3
Implicita	22	743	393	419.8

The prepupal stage is highly variable and may extend from 2 to 33 days with the different species. The extremes and averages of the 18 species are noted in Table LXII.

TABLE LXII.—The length of the prepupal stage of all species of *Phyllophaga* observed.

SPECIES.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Affabilis	5	5	4	4.2
Bipartita	9	17	3	9.2
Corrosa	25	15	2	6.6
Submucida	18	10	2	7.2
Vehemens	3	7	7	7.0
Tristis	3	7	5	6.0
Fusca	1	6	6	6.0
Crenulata	2	8	7	7.5
Longitarsa	58	16	2	4.1
Prætermissa	15	12	3	6.7
Glabricula	2	6	2	4.0
Rugosa	122	30	2	9.2
Rubiginosa	137	12	2	7.0
Lanceolata	48	12	2	4.8
Futilis	23	11	5	7.4
Crassissima	406	33	2	7.6
Hirticula var. comosa	25	16	4	8.7
Implicita	70	11	2	6.7

The data on the complete larval stage, including the active and prepupal stages, are also highly variable, depending on whether the species has a one- two- or three-year life cycle. Table LXIII shows it may vary from 115 to 802 days in all species under discussion.

TABLE LXIII.—The length of complete larval stage of all species of *Phyllophaga* observed.

SPECIES.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Affabilis	5	361	338	347.0
Bipartita	6	788	411	707.3
Corrosa	25	769	382	516.4
Submucida	13	697	663	676.5
Vehemens	3	787	421	546.0
Tristis	6	433	115	374.6
Fusca	1	418	418	418.0
Crenulata	1	385	385	385.0
Longitarsa	62	671	300	337.0
Prætermissa	4	780	395	680.0
Rugosa	21	785	402	685.5
Rubiginosa	37	802	401	755.3
Lanceolata	37	692	331	647.1
Futilis	17	432	394	415.5
Crassissima	101	790	414	558.7
Hirticula var. comosa	3	765	753	757.7
Implicita	24	751	400	425.5

Among the 17 species here discussed, the pupal stage varied from 6 days in the case of *P. longitarsa* to 58 days with *P. crassissima*. The extremes and averages for all species are presented in Table LXIV.

TABLE LXIV.—The length of the pupal stage of the species of *Phyllophaga* under consideration.

SPECIES.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Affabilis	5	16	14	14.6
Bipartita	6	35	24	30.3
Corrosa	22	26	22	24.6
Submucida	19	29	18	23.5
Vehemens	3	27	23	25.3
Tristis	5	28	17	21.4
Fusca	1	27	27	27.0
Crenulata	1	21	21	21.0
Longitarsa	50	17	6	13.4
Prætermissa	13	28	21	24.9
Glabricula	2	18	17	17.5
Rugosa	127	50	23	28.8
Rubiginosa	154	38	20	27.3
Lanceolata	77	25	6	15.0
Futilis	22	35	23	27.7
Crassissima	428	58	9	28.1
Hirticula var. comosa	25	36	22	27.7
Implicita	85	37	16	24.1

The computed life cycles of all species under observation in this study are given in Table LXV.

TABLE LXV.—The computed life cycle of all the species of *Phyllophaga* observed.

SPECIES.	Egg stage.			Larval stage.			Pupal stage.			Life cycle.		
	Number of days.			Number of days.			Number of days.			Number of days.		
	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.
Affabilis	16	10	14.3	361	338	347.0	16	14	14.6	393	362	375.9
Bipartita	24	11	16.6	788	411	707.3	35	24	30.3	847	446	754.2
Corrosa	28	11	18.1	769	382	516.4	26	22	24.6	823	415	559.1
Submucida	20	13	14.1	697	663	676.5	29	18	23.5	746	694	714.1
Vehemens	28	11	19.8	787	421	546.0	27	23	25.3	842	455	591.1
Tristis	23	10	17.2	433	115	374.6	28	17	21.4	484	142	413.2
Fusca	28	16	19.5	418	418	418.0	27	27	27.0	473	461	464.5
Crenulata	20	14	18.2	385	385	385.0	21	21	21.0	426	420	424.2
Longitarsa	19	7	12.7	671	300	337.0	17	6	13.4	707	313	363.1
Prætermissa	23	12	17.6	780	395	680.0	28	21	24.9	831	428	722.5
Rugosa	29	14	19.5	785	402	685.5	50	23	28.8	864	439	733.8
Rubiginosa	24	11	17.0	802	401	755.3	38	20	27.3	864	432	799.6
Lanceolata	29	10	15.8	692	331	647.1	25	6	15.0	746	347	677.9
Futilis	38	11	21.1	780	394	415.5	35	23	27.7	853	428	464.3
Crassissima	27	8	16.1	790	414	558.7	58	9	28.1	885	431	602.9
Hirticula var. comosa	30	11	17.9	765	753	757.7	36	22	27.7	831	786	803.3
Implicita	31	10	18.2	751	400	425.5	37	16	24.1	819	426	467.8

Table LXVI shows the number of specimens of each species reared to adult from egg and also indicates the length of the life cycle. *P. affabilis* alone has only a one-year cycle in Kansas. *P. tristis* and *P. longitarsa* have a one- or a two-year cycle. *P. crenulata, P. submucida, P. fusca,* and *P. futilis* have a two-year cycle, but the data indicate the possibility of a three-year period. The others may have a two- or a three-year period except in the case of *P. hirticula* var. *comosa* in which a three-year period only was observed.

TABLE LXVI.—The life cycle of all *Phyllophaga* reared and the number of rearings.

SPECIES.	Total.	Number of one-year individuals.	Number of two-year individuals.	Number of three-year individuals.
Affabilis	4	4	0	0
Bipartita	3	0	1	2
Corrosa	19	0	16	3
Submucida	13	0	13	0
Vehemens	3	0	2	1
Tristis	4	1	3	0
Fusca	1	0	1	0
Crenulata	1	0	1	0
Longitarsa	48	47	1	0
Prætermissa	2	0	1	1
Rugosa	21	0	5	16
Rubiginosa	29	0	2	27
Lanceolata	23	2	21	0
Futilis	16	0	16	0
Crassissima	81	0	54	27
Hirticula var. comosa	2	0	0	2
Implicata	22	0	21	1

As previously mentioned, the writer has reported elsewhere (1919 and 1920) on the life cycle of seven additional species of *Phyllophaga* which were studied in connection with this investigation. The work reported in 1919 and 1920 has been continued, and with an increased number of beetles reared to maturity the minimum, maximum, and average figures have changed somewhat. For the purpose of comparison with those herein reported, the revised data based on actual rearings are presented in Table LXVII.

With the exception of four species, *P. affabilis, P. submucida, P. longitarsa,* and *P. lanceolata,* all of the species discussed, pupate in the fall and pass the winter as adults. Accordingly, in considering the life cycle, eight or nine months should be added to the figures presented in the foregoing tables to arrive at the total period of life from the time of oviposition to the normal time of death. In the four exceptions noted above, pupation occurs in the spring or early summer and the adults emerge soon after transformation.

To further compare the life cycle of *Phyllophaga,* it should be noted that Davis (1916) found a two-year cycle in *P. tristis* and

P. lanceolata; a two- and three-year period for *P. burmeisteri, P. futilis,* and *P. implicata;* a three-year period for *P. arcuata, P. bipartita, P. congrua, P. fraterna, P. fusca, P. grandis, P. hirticula, P. ilicis, P. inversa, P. rugosa,* and *P. vehemens,* and a three- and possibly a four-year cycle in *P. crassissima* and *P. crenulata.*

Smyth (1917), in Porto Rico, found for 14 complete records of *P. vandinei* Smyth an average period of 306 days from egg to adult with a maximum of 395 days and a minimum of 212 days, or expressed in months, from 7 to 13 months with an average of about 10 months. Except in the case of *P. tristis,* this is one of the shortest life cycles reported. It is somewhat shorter, but is probably comparable to the one-year periods of *P. affabilis* and *P. longitarsus* as here recorded. Criddle (1918) reports that *P. nitida* LeC., *P. drakii* Kirby, *P. anxia* LeC., and *P. rugosa* Melsh. have in Manitoba, Canada, a four-year life-cycle, but gives no pertinent data on the length of the various stages.

Based on the actual rearings in the present study the summaries of the life cycles of the species under observation are given in Table LXVII.

TABLE LXVII.—Summary of the life cycle based on actual rearings.

SPECIES.	Number of individuals.	Number of days.			Life cycle in years.
		Maximum.	Minimum.	Average.	
Affabilis	4	389	369	376.6	1
Bipartita	3	815	495	703.0	2 and 3
Corrosa	19	791	429	501.8	2 and 3
Submucida	13	734	708	720.3	2
Venemens	3	838	459	591.3	2 and 3
Tristis	4	474	137	380.0	1 and 2
Fusca	1	461	461	461.0	2
Crenulata	1	424	424	424.0	2
Longitarsa	48	701	327	356.4	2 and 3
Prætermissa	2	811	434	628.5	2 and 3
Rugosa	21	836	445	735.7	2 and 3
Rubiginosa	29	839	447	791.5	2 and 3
Lanceolata	23	723	357	675.7	1 and 2
Futilis	16	494	457	469.7	2
Crassissima	81	816	449	588.3	2 and 3
Hirticula var. comosa	2	789	780	784.5	3
Implicata	22	790	442	470.4	2 and 3

The Life History of the Rutelinæ

The members of the subfamily Rutelinæ are noted for their beauty, rivaling in this respect the Cetoniinæ which they excel in metallic splendor. The American species of the subfamily are divided into two tribes, the *Anomalini* and the *Rutelini.* In the following discussion, one species of the *Anomalini, Anomala innubia*

Fab., and two species of the *Rutelini, Pelidnota punctata* Linn. and *Cotalpa lanigera* Linn., are considered.

The *Anomalini* contain several North American species that are notably injurious to crops in both the larval and the adult stages. The larvæ attack the roots and the adults the foliage, especially the blooms. The most important species, and one that has created considerable attention in the last few years, is the introduced Japanese beetle, *Popillia japonica* Newm. The injuries caused by this beetle have warranted the expenditure of a large amount of money, and a large corps of entomologists are now working under state and government supervision in New Jersey, where the species is causing an immense amount of damage. Perhaps the next in importance is the genus *Anomala* which contains many species widely distributed over the world. In the United States, *Anomala binotata* and *Anomala undulata* are two of the better known species. The life cycle of *A. binotata* has been found by the writer (1918) to have a one-year period of growth. The eggs are laid in the spring, the grubs mature by fall, and the beetles hibernate in the soil over winter.

Strigoderma arboricola Fab., also belonging to the *Anomalini,* is injurious in the adult stage to wild and cultivated roses. Hayes (1921) has reported a one-year life cycle. This species differs from *Anomala binotata* in that it passes the winter in the larval stage and pupates in the spring.

The tribe *Rutelini* is composed of larger and generally more brightly metallic species than the *Anomalini,* and according to Casey (1915) the tribe is particularly well developed on the American continents. The tribe includes some of the most beautifully resplendent insects in the world. Two species, *Pelidnota punctata* and *Cotalpa lanigera,* are of considerable economic importance in certain parts of the United States. In so far as the writer can ascertain, the life cycles of these species have not been previously reported.

ANOMALA INNUBIA FABRICIUS

Description and Synonymy.—*Anomala innubia* Fabricius is quite variable in color and has been the cause of considerable confusion in the literature. It was described by Fabricius (1787) as *Melolontha innubia* in the following words:

"M. glabra nigra thoracis margine, abdomine femoribusque testaceis. Habitat—Mus. D. Hunter. Parva, nitida, Caput nigrum ore antennisque flavis. Thorax punctatus, niger, dus margine lat-

erali testaceo. Elytra substriata, nigra, immaculata—Pectus nigrum. Abdomen testaceum. Pedes nigri, femoribus testaceis."

According to Ohaus (1902), who made an examination of Fabricius' type of *innubia,* this is the species that Burmeister (1844) listed as *minuta.* Horn (1884) in his study of the genus placed *innubia* as a doubtful synonym of *minuta.* Ohaus has demonstrated that *minuta* Burm. is a southern species without cleft tarsal claws. Casey (1915) has shown that Blatchley's variety, *A. undulata dubia* is a synonym of *A. innubia.*

Three color forms were found in the study reported here, one entirely black (Pl. III, fig. 2), another testaceous with a darkened area on the thorax (Pl. III, fig. 1), and a variable intermediate type (Pl. III, figs. 3 and 4) which show the elytra to be variously mottled with transverse rows of dark spots. These color forms were observed to mate indiscriminately. For example, black individuals mated together, or with spotted or yellow forms, and conversely, spotted or yellow forms mated *inter se* or with black individuals. Eggs laid by any of the forms may produce adults of all three forms. It is possible that these color forms are produced in Mendelian ratios. At any rate, this species apparently affords good material for a genetic study of the lamellicorns. In the present discussion, where the different color forms are separately discussed, for the purpose of convenience, they are called "black," "spotted," and "yellow varieties." The term "variety" being used merely for the sake of convenience and uniformity, and not in its strictly taxonomic sense.

Blatchley's description (1910), which is more complete than the original, is here given:

"Oval, rather robust. Color very variable, usually dull yellow with the front, a large spot on the thorax and one to three transverse rows of spots on elytra, piceous; sometimes wholly black or piceous, shining. Head rather densely and finely punctured; clypeus nearly semicircular in outline, the sides divergent behind the middle. Thorax one-half wider than long, sides curved, surface coarsely and rather deeply but not densely punctured. Elytra with rows of coarse, deep, closely placed punctures, the rows near the sutures very irregular. Pygidium rugulose at base, smoother at apex. Claw joint of tarsus distinctly toothed beneath when viewed from the side. Length, 6 to 7.5 mm."

He further notes that some specimens occur in which the rows of spots on the elytra are wholly lacking, which give the elytra a uniform dull yellow color.

The sexes may be distinguished by the following characters: In the male the antennal club is as long as the funicle, while in the female it is shorter; and the posterior, ventral, abdominal segment of the male is emarginate on the posterior margin, while in the female it is broadly rounded.

Distribution.—Fabricius did not know the locality from which his specimens had come when he described the species. Leng (1920) and Casey (1915) say that *A. innubia* occurs from Pennsylvania to Florida and westward to Nebraska. Blatchley (1910) notes it is common in Indiana and occurs throughout the state.

In Kansas the species probably occurs throughout the state, having been taken in Riley county and as far west as Dodge City.

Relative Abundance.—The study of *Anomala innubia* began in the fall of 1919 when a number of grubs were collected in a cornfield. They were kept over winter in individual salve boxes in the laboratory. The beetles began to mature in early June. Five beetles only were collected in the fields during this season. These were observed flying June 21. One specimen was noted flying at 10:00 a. m. and four were taken in the curl of young corn plants. This was the first clue to its diurnal habits. A related species, *A. undulata,* and one often confused with *A. innubia,* is nocturnal in flight and feeding habits.

From the beetles maturing in the cages in 1920, eggs were obtained from which the life-history studies were started. In 1921 and 1922 beetles were found slightly more abundantly, principally on heads of growing wheat, in the curl of corn plants, and on neighboring weeds, chiefly mare's tail. Black, yellow, and spotted specimens were found and their relative numbers noted, no effort being made to distinguish the varying degrees of spottedness.

Table LXVIII tabulates the collections of 1921 and 1922 as to color.

TABLE LXVIII.—The relative abundance of different colors of *A. innubia.*

YEAR.	Black.	Spotted.	Yellow.	Total.
1921	29	8	63	100
1922	9	2	18	29
Total	38	10	81	129

Attraction to Lights.—This beetle has been taken once only in these studies at electric lights. Blatchley (1910) says it occurs at electric lights in Indiana.

Period of Light.—As noted above, the species is chiefly day flying and is most active during the early morning hours. By noon most of the beetles have secluded themselves in such places as the curl of corn plants where they remain inactive apparently until the following day. The period of flight is extremely short, as noted in the two years, being only seven days in 1921 and eleven days in 1922. The earliest flight was June 3 in 1921 and the latest June 24 in 1922. The data relating to periods of flight are summarized in Table LXIX.

TABLE LXIX.—The flight period of *A. innubia.*

YEAR.	First flight.	Last flight.	Length of flight (days).
1921	June 3	June 10	7
1922	June 13	June 24	11
Average	June 8	June 17	9

It may be mentioned that the beetles are comparatively strong fliers. They were noted, when disturbed, to ascend rather high and soon to pass beyond the range of vision.

Food Habits.—Since this species has been confused in the literature with *A. undulata* and *A. minuta* it is difficult to ascertain what references apply. Popenoe (1881) recorded *A. undulata* as feeding on the heads of growing wheat when in the "milk" stage. It is probable that this reference applies to *A. innubia.* He also states that *A. innubia* is commonly found on corn in company with *A. undulata.* Likewise, Chittenden (1902) states that *A. undulata* was seen "affecting" growing wheat. There are some references to the food habits of *A. minuta,* but since these are from the southern states, it is hardly probable that they apply to *A. innubia.* Blatchley (1910) states that *A. innubia* occurs on the flowers of wild rose and Jersey tea.

In the Kansas studies reported here, the beetles were collected on the following plants: Wheat, corn, einkorn, *Oenothera,* mare's tail, foxtail, smartweed, and sorghum. In wheat the beetles were usually found on bearded heads, but in one instance a beetle was collected on a beardless variety.

Mating and Oviposition.—The proportion of sexes of this species was not recorded.

In 1920, mating was first noted in the cages on June 22, but it had probably occurred earlier since eggs were found the following day. In 1921, the first mating was observed in the field on June 4. When one yellow female was seen with one black and two yellow males, all three of which were trying to mate with the female. These were observed on the soil at the base of a wheat plant. At 3:00 p. m. of the same day, a black and a yellow individual were observed mating. On June 10 a yellow male was noted with a spotted female on a wheat leaf at 8:00 a. m. In rearing cages, black individuals were noted mating with blacks, and yellow individuals with yellow. It is evident that the color variation is not due to sex differences. In 1920, oviposition began June 23 and continued until June 29. In 1921, the first eggs were found June 8 and the last June 23. One female mating in the cages June 4 and June 9 laid 17 eggs June 9, giving a preoviposition period of five days. In all, this female laid 20 eggs.

Description of Egg.—The eggs of *A. innubia* when freshly laid are about 1.5 mm. long and 0.75 mm. wide and as development proceeds they become about 1.75 mm. long and 1 mm. wide. They are, therefore, elongate-oval when freshly deposited and later assume a more spherical form. They are pearly white in color.

Length of Egg Stage.—The length of the egg stage was obtained from 119 eggs from black and yellow individuals. The period of development grouped according to the color of the female parent is indicated in Table LXX.

TABLE LXX.—The length of the egg stage of *A. innubia*.

YEAR.	Number of eggs.		Number of days.					
			Maximum.		Minimum.		Average.	
	Black.	Yellow.	Black.	Yellow.	Black.	Yellow.	Black.	Yellow.
1920	10	42	13	19	11	12	12.6	14.9
1921	9	58	19	17	14	12	16.7	14.6
	19	100	19	19	11	12	14.6	14.7

The average periods of development for the two years are 14.6 and 14.9 days for the blacks and the yellows respectively. The differences no doubt are within the limits of experimental error.

Description of Larva.—The newly hatched larva is about three millimeters long and creamy white in color. The contents of the alimentary tract soon darken the body, however, and the head capsule turns to a pale yellow. In the first instar the darkened posterior part of the body extends farther cephalad than in most other young grubs, giving the grubs, in general, a darker appearance. The young grub is quite active and crawls rapidly on its feet. When full grown the grubs are about 15 mm. long and after the prepupal period they are generally one to two millimeters shorter.

Length of Larval Stage.—The grubs molt twice during development. The length of the instars was not obtained for the specimens hatching in 1920. Six examples were recorded from the eggs hatching in 1921. Unfortunately, none of these reached the pupal stage, and data for the first and second instar only are available. These are recorded in Table LXXI.

TABLE LXXI.—The length of the first and second instars of *A. innubia*.

COLOR.	Date hatched.	First molt.	First instar (days).	Second molt.	Second instar (days).
Yellow	June 28	July 15	17	Aug. 3	19
Yellow	June 30	July 15	15	Aug. 3	19
Black	July 6	Aug. 3	28	Aug. 15	12
Black	July 6	Aug. 3	28	Aug. 24	21
Black	July 6	Aug. 5	30	Aug. 18	13
Black	July 7	Aug. 3	27	Aug. 15	12
Average			24.1		16

The length of the prepupal stage was determined for 21 cases, including 12 grubs collected in the field. The results are shown in Table LXXII from which it will be seen that the period varied from two to seven days with an average of 3.4 days.

TABLE LXXII.—The length of the prepupal stage of *A. innubia*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared grubs	9	6	2	3.3
Collected grubs	12	7	2	3.6
	21	7	2	3.4

The length of the complete larval stage was observed in 13 cases. The eggs all hatched in July, 1920, and most of the grubs pupated in May, 1921. Two pupated in December, 1920, making for these individuals complete larval stages of 147 and 148 days. These died in the pupal stage and it is uncertain whether they would have passed the winter as pupæ or as adults. Like the others, they had been kept in the rearing cave under fairly constant temperature and it is doubtful if the species would, in nature, pupate in December in the latitude of Kansas. The 11 specimens pupating in May, 1921, had an average period of 315.3 days, with extremes of 309 and 319 days. The data for the 13 individuals are given in Table LXXIII.

It will be noted that the two larvæ which pupated in December reduced the average to 289.5 days, whereas for the 11 larvæ it was 315.3 days, and for the other two 147.5 days.

TABLE LXXIII.—The length of the complete larval stage of *A. innubia.*

HATCHED.	Pupated.	Length of stage (days).
July 5, 1920	May 20, 1921	319
July 5, 1920	May 20, 1921	319
July 6, 1920	May 19, 1921	317
July 7, 1920	Dec. 2, 1920	148
July 8, 1920	Dec. 2, 1920	147
July 8, 1920	May 18, 1921	314
July 9, 1920	May 21, 1921	316
July 9, 1920	May 21, 1921	316
July 10, 1920	May 21, 1921	315
July 11, 1920	May 20, 1921	313
July 11, 1920	May 23, 1921	316
July 12, 1920	May 23, 1921	315
July 15, 1920	May 20, 1921	309
Average		289.5

Food of Grubs.—The grubs of this species have been found abundantly in corn and wheat fields. They have also been found more sparingly at roots of Johnson grass and sunflowers.

Description of Pupa.—The pupa of *A. innubia* are about 8 mm. long and 5 mm. wide. When freshly transformed they are creamy white in color and darken before emergence in variable degrees, depending on whether the adults are to be yellow, spotted, or black. In the later case, the prothorax, except the lateral margins, becomes entirely black. The wing covers are almost black, the antennæ and legs yellowish brown and the abdomen a pale yellow. Complete coloration is not acquired until some time after emergence of the adult.

Length of Pupal Stage.—The length of the pupal stage was determined for 79 specimens. It was found to vary from 10 to 18 days with an average of 13 days. The larval period for individuals reared from eggs and those collected in the field are shown in Table LXXIV.

TABLE LXXIV.—The length of the pupal stage of *A. innubia.*

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared grubs	10	14	10	11.6
Collected grubs	69	18	10	14.5
	79	18	10	13.0

Life Cycle.—It would appear from the above that, normally, eggs of *A. innubia* are laid in June and the larvæ pass the winter and pupate in May. The pupal stage averages 13 days and the adults fly soon after transformation. There is apparently no difference in the length of the life cycle corresponding with a difference in color.

The computed life cycle calculated from the maximum, minimum, and average periods of the three stages approximates the results obtained in the actual rearings. The data so obtained, omitting the two individuals pupating in December, are shown in Table LXXV.

TABLE LXXV.—The computed life cycle of *A. innubia.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	100	19	11	14.6
Larval	11	319	309	315.3
Pupal	79	18	10	13.0
		356	330	342.9

PELIDNOTA PUNCTATA LINN

Description and Synonymy.—*Pelidnota punctata* Linn. was described by Linnæus in his tenth edition of Systema Naturæ in 1758, in which he gives the habitat as "India." The species was placed in the genus *Melolontha* by Fabricius (1775) and then transferred to *Rutela* by Latrielle (1807) where it remained until 1819 when Mac-

Leay created the new genus *Pelidnota,* where it was placed and has since remained.

The beetle (Pl. I, fig. 4) is about 20 to 25 mm. long and 13 to 15 mm. wide. The dorsal surface is yellowish-clay in color, with a faint metallic luster. The head and thorax are slightly darker than the elytra. Certain black areas with a greenish luster occur on the head and scutellum. The thorax has a single black spot near each lateral margin and each elytron has three distinct black spots on the lateral margins, one near the humerous, one near the middle, and one near the apical declivity. The ventral surface of the abdomen is brownish-black with a faint green luster.

The original description by Linnæus is here quoted for its historical value.

"Scarabaeus punctatus: 39 S. muticus niger, thorace elytrisque testaceis. Punctis octo nigris. M. L. U. Habitat in India. Thorax puncto untrinque nigro laterali notatus."

Distribution.—Burmeister (1844) gave the distribution of this species as from Canada to South Carolina. Saunders (1874) says it is confined in Canada mainly to Ontario. Casey (1915) gives the distribution as from New York and Virginia to Michigan and Iowa and notes that the species is abundant. Leng (1920) gives Connecticut as the eastern range of the species and considers three varieties of the species which are distributed as follows:

Var. *strenua* Casey, Indiana.

Var. *brevis* Casey, Long Island.

Var. *notata* Blanchard, Mexico, Texas, and Florida.

The collection of the Kansas State Agricultural College contains specimens found throughout the state of Kansas as far west as Dodge City, and the Cornell collection has examples from Douglas county, Kan., Ithaca, N. Y., Honeoye, N. Y., and Ohio. There are also three specimens from Billy's Island, Okefenakee Swamp, Ga., which have only faint traces of the black spots and specimens from LaBelle, Fla., with smaller spots than in the common form.

Relative Abundance.—This species, although well known and at times seriously injurious in some regions, has not appeared in large numbers during the six years it was under observation at Manhattan. The total number collected from lights, food plants, and reared specimens amounted to 362. This number compares with the rarer *Phyllophaga* and in no way approaches the numbers of the more common species. Table LXXVI shows the number of beetles collected at lights, from food plants, from miscellaneous situations, such as rotten logs, and the numbers reared.

TABLE LXXVI.—The relative abundance of *Pelidnota punctata.*

SOURCE.	1917.	1918.	1919.	1920.	1921.	1922.	Total.
At lights	25	21	6	67	67	79	265
On food	1	0	0	25	0	0	26
Miscellaneous	0	1	15	13	1	0	30
Reared from collected grubs	1	1	9	0	2	8	21
Reared from egg	0	0	0	0	1	19	20
Total	27	23	30	105	71	106	362

During the six years of observation there were only two years, 1920 and 1922, in which any considerable number of the beetles appeared. The data, nevertheless, show that there is an overlapping of the broods each year and there is a faint indication of a two-year life cycle in the numbers appearing in 1920 and 1922 with a small number during the intermediate year.

Period of Flight.—This species has only one period of flight during the season in contrast to *Ligyrodes relictus* and the species of *Euphoria* which have a spring and late summer or fall flight. Mating takes place above the surface of the soil, generally on food plants and the flight is for this purpose as well as for the procuring of food. The length of the flight varied in the different years from a minimum of 31 days in 1921 to a maximum of 87 days with a six-year average of 52 days. The earliest appearance of the beetles was May 31 and the last specimen collected in flight was on September 2 in 1920. These and other data are given in Table LXXVII from which it may be noted that the beetles are present at lights throughout the greater part of the summer. The length of the period of flight, however, does not indicate the length of adult life, but rather points to an indefinite and prolonged period of emergence.

TABLE LXXVII.—Period of flight of *Pelidnota punctata.*

YEAR.	First flight.	Last flight.	Length of flight (days).
1917	June 23	July 23	31
1918	June 4	July 28	55
1919	June 17	July 21	35
1920	June 8	Sept. 2	87
1921	May 31	July 19	50
1922	June 10	Aug. 2	54
Average			52

Soil Preferences.—No special types of soil were noted as favorites for these beetles. They were collected in upland soils, heavy bottom soils and in pure sand on the dunes of the Kansas river.

Food Habits. This species, in the adult stage, is in most regions a feeder on cultivated grapes. In the vicinity of Manhattan they were not plentiful on the cultivated varieties, most of the collections on food plants having been made on wild grapes. One beetle was found in 1917 feeding on spinach in a garden. There are numerous references in the literature to the beetle feeding on grapes, and Riley (1871) has noted it feeding on Virginia creeper.

Proportion of Sexes.—Casey (1915) states that the males of this species are much less abundant than the females. In only one year (1918) of the six in which sexes were separated in the present study have the females appeared in larger numbers. The total of the collections as shown in Table LXXVIII shows that the males were almost twice as abundant as the females. In all the collections at lights the males have predominated.

Mating and Oviposition.—Mating was observed several times on wild grape at night. It was also observed in a cage in the laboratory where it occurred on the surface of the soil at 2:00 p. m. A somewhat perverted mating habit was noted in the laboratory when a male of this species was observed attempting to mate with another scarabæid, *Pollyphylla hammondi* LeC. The specimens were confined in a cage after having been collected at lights the previous evening. The *P. hammondi* had died and the *P. Punctata* male had its penis inserted in the anal opening of the dead individual. In another instance a male *Cotalpa lanigera* was seen trying to mate with a male *Pelidnota punctata.*

Oviposition occurs in June, July, and August, having been noted as early as June 19 and as late as August 17. One female was observed in the act of oviposition under a log at 8:30 a. m. Eggs are laid singly in moist soil beneath rotten logs or near rotten stumps in order that the hatching larvæ may be close to a source of food which they find by immediately boring into the wood of the stump or fallen log. Eggs found in such situations are frequently observed to be surrounded by a small ball of earth as is the case with eggs of the genus *Phyllophaga.* Often this ball is broken in digging the eggs from the soil and therefore goes unnoticed.

Description of Eggs.—As in other species of the family Scarabæidæ, the eggs are pearly white in color and when freshly laid are about 2 mm. long and 1.5 mm. wide and of an elongate-oval shape.

TABLE LXXVIII.—The proportion of sexes of *Pelidnota punctata*.

SOURCE.	1917.			1918.			1919.			1920.			1921.			1922.			Total.		
	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.	♀	♂	Total.
At lights	0	0	0	11	10	21	1	5	6	15	52	67	0	0	0	23	56	79	50	123	173
On food plants	0	0	0	0	0	0	0	0	0	13	12	25	0	0	0	0	0	0	13	12	25
Miscellaneous	0	0	0	1	0	1	3	12	15	6	7	13	0	0	0	0	0	0	10	19	29
Reared from collected grubs	0	1	1	1	0	1	7	2	9	0	0	0	0	2	1	4	4	8	12	9	21
Reared from egg	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	7	12	19	8	12	20
Total	0	1	1	13	10	23	11	19	30	34	71	105	1	2	3	34	72	106	93	175	268

As development proceeds they become somewhat larger and more spherical.

Length of Egg Stage.—A total of 979 eggs have hatched under observation in the laboratory during five seasons of the six. The exact length of the egg stage was not noted in 1919. The data for other years are shown in Table LXXIX. The average period of development was 14.9 days, with extremes of 8 and 26 days.

TABLE LXXIX.—The length of the egg stage of *Pelidnota punctata.*

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1917	9	18	13	16.0
1918	21	20	14	15.0
1920	392	26	8	15.1
1921	391	18	8	13.3
1922	166	21	8	15.5
	979	26	8	14.9

Description of Larva.—The grubs of *P. punctata* are completely white when first hatched, but the head soon darkens to a light brown and when food has been eaten the alimentary tract shows dark through the body wall. The last ventral abdominal segment lacks the double row of longitudinal spines (Pl. X, fig. 5) which is present in *Phyllophaga.* The spines of the triangular patch are few and scattered and not curved at the tips. Riley (1870) has given a good description of this larva as follows:

"Length, 2 inches; clumsy, moving on the side. *Head,* bright chestnut-brown, smooth, rounded, with a short, impressed longitudinal line on the top, and three shallow impressions in front; epistoma trapezoidal and darker; labrum rough, irregularly punctate, and beset on the margin with a few stiff rufous hairs; antennæ . . . as long as epistoma and labrum together, 4-jointed exclusive of bulbus or tubercle in which they are inserted; joints cylindrical, proportioned in lengths as 2, 6, 4, 1, the terminal joint being often a mere bud; mandibles strong and black, with three denticulations at tip, and a very slight tooth at inner basal portion; maxillæ brown and subcylindrical on outside, angulated on inside, bearing two lobes, each terminating in an inwardly curved coriaceous tooth, and each furnished on their inner narrow edge with stiff bristles, the outside one arising close by base of palpus, the inside one extending lower down and recalling, by its form, the terminal joint of the front leg of a scorpion; maxillary palpi 4-jointed, joints cylindrical, short, very gradually longer and larger from 1 to 4, the terminal joint more pointed and narrower than the others; labrum quadrangular, labial palpi

2-jointed, the palpigerous piece strongly beset with bristles. Body, smooth with but a few wrinkles on thorax; polished translucent white, with faint bluish marblings on all but thoracic joints, which are slightly narrower than the rest; a narrow vesicular dorsal line, and a very slight yellowish horny plate in a depression on joint 1; a very slight pubescence observable, and a transverse tergal row of sparse but tolerably long hairs on posterior part of each joint; more dense and conspicuous hairs on anal joint, which joint is short, cut off squarely, with a heart-shaped swelling . . . sunk into a circular depression, each lobe of the heart with a darker oval coriaceous elevation; spiracles subelliptical, dark chestnut-brown, placed on a prominent swelling, the lateral openings all facing the head, the first on joint 1, the rest on joints 4, 5, 6, 7, 8, 9, 10 and 11, gradually becoming smaller and smaller from first to last. Legs . . . horny, light brown and covered sparsely with hairs; coxæ long and stout, with a round swelling at lower anterior edge; femora cylindrical, sometimes distinctly, at others indistinctly, separated from tibiæ, sometimes prolonged into a thorn below, with a distinct carina along the inside, at others not; tibiæ cylindrical, incrassated anteriorly, especially below; tarsi cylindrical and terminating in a distinct claw."

Length of Larval Stage.—The larvæ of this species live in rotten stumps and logs and are extremely difficult to rear in the laboratory. Only one individual was reared in salve boxes. This one larva required 645 days to develop. The length of the first and second molts were observed in 12 instances, but the time between the second molt and the prepupa was not noted because only one individual developed that far and in this particular instance the second molt was not observed at the time of occurrence. Accordingly, the complete active stage was not noted. The data on the length of the larval stage are summarized in Table LXXX.

TABLE LXXX.—The length of the larval stage of *Pelidnota punctata*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	12	87	54	71.5
First molt to second—occurring the same season	5	22	8	13.6
First molt to second—when second occurs the following season	7	316	277	289.0
Prepupal stage	13	9	3	5.3
Total larval stage	1	645	645	645.0

The grubs may molt twice the same season they hatch, or the second molt may be postponed until the following year. The first molt, it will be seen, occurred on the average 71.5 days after hatching, with a range of 54 to 87 days. The data for the second instar

are divided according to whether the second molt occurs the first season or the second. The average interval was 13.6 days for those which molted the first season, with extremes of 8 and 22 days. The average period for the second molt when postponed is 289 days and it varied from 277 to 316 days. The second molt, therefore, may occur in July, August, or September of the second season. The period of the second molt may vary from 72 to 396 days. The period after hatching for all those molting the first season averaged 77.5 days, and for those molting the second season, 366.1 days.

The length of the prepupal stage varied from 3 to 9 days with an average of 5.3 days and the complete larval period, as noted above, required 645 days in the only case observed.

Food of Grubs.—The grubs of this species were found in nature developing in elm logs and stumps. Fletcher (1880) has found them in rotten stumps and roots of pear trees. No definite study relating to their preferred food has been made in the present work.

Length of Pupal Stage.—The length of the pupal stage of *P. punctata* was found to vary from 13 to 24 days, with an average of 19 days. These figures are for 21 individuals, 20 of which were pupæ of grubs collected in the field. The data are tabulated in Table LXXXI.

TABLE LXXXI.—The length of the pupal stage of *Pelidnota punctata*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared grubs	1	13	13	13.0
Collected grubs	20	24	16	19.4
	21	24	13	19.0

The pupa is said by Fletcher (1880) to be inclosed in a cocoon of chips. None were observed in such a cocoon in laboratory rearings in our present study, but this may be due to the artificial conditions.

Life Cycle.—The one individual reared from egg to adult had a life cycle of approximately two years. The egg was laid in early July, 1919, and the beetle emerged from the pupa July 11, 1921. As a check on this rearing it should be noted that in July, 1920, a number of freshly hatched grubs were placed in a large can containing crushed and rotting fragments of elm wood and left undisturbed in the rearing cave. Upon examination two years later

(July 13, 1922) there were found in the can 12 male and 17 female beetles which had quite recently matured, thus indicating a two-year period.

COTALPA LANIGERA LINN

Description and Synonymy. *Cotalpa lanigera* (Pl. II, fig. 1) was described by Linnæus in the genus *Scarabœus* and later transferred to the genus *Melolontha* by Fabricius. In Schoenherr's Synonymia Insectorum it is placed in the genus *Rutela* and Dejean's catalogue discusses it in *Areoda*. Burmeister (1844) established the genus *Cotalpa* in which he placed *lanigera* where it has since remained. He has shown that *Areoda scutellaris* Dejean is a synonym of *C. lanigera*. Casey (1915) has described a subspecies from Indiana, Iowa, and Wisconsin which he named *obesa*. In the same work he described a new species, *Cotalpa vernicata*, from Virginia and New York which is listed by Leng (1920) as of subspecific rank along with *obesa*.

The species was described by Linnæus as follows:

"S. muticus subtus lanatus, capite thoraceque auratis, elytris flavis. M. L. U. Habitat in India. Labium futura distinctum a capite. Elytra sulphurea."

Blatchley (1910) has further described the beetle and his description is here quoted:

"Broadly oval, robust. Head, thorax and scutellum greenish or yellowish with a strong metallic lustre; under surface piceous, bronzed, rather densely clothed with long, wool-like hair, the legs sometimes paler; elytra yellowish, feebly shining. Thorax twice as broad as long, sides broadly rounded, surface very finely and sparsely punctate. Elytra with a depression each side near the humerous, their punctures coarser than those of the thorax and arranged in rows which are visible only beneath a lens. Length, 20 to 26 mm."

Distribution.—*Cotalpa lanigera* is widely distributed over the eastern United States, being reported by Leng (1920) as occurring in Connecticut, New Jersey, Indiana, and Florida. Casey (1915) cites its occurrence in New York and New Jersey, and states that it is confined to the colder parts of North America. Harrington (1890) states that is occurs in a large part of Canada but not at Ottawa.

Relative Abundance.—During the five years, only 301 beetles of this species have been found; of these 60 were taken at lights, 219 on food plants, and 12 have been reared from egg to adult. These data with the numbers reared from collected grubs and those collected in the soil are shown in Table LXXXII.

TABLE LXXXII.—The relative abundance of *Cotalpa lanigera.*

SOURCE.	1917.	1918.	1920.	1921.	1922.	Total.
At lights	5	15	5	13	22	60
Food plants	0	0	212	0	7	219
In soil	0	0	1	0	0	1
Reared from collected grubs	0	0	0	0	9	9
Reared from egg	0	0	0	0	12	12
Total	5	15	218	13	50	301

According to Davis (1916) the grubs of this species in some sections rank close to those of *Phyllophaga* in economic importance. In the "thumb district of Michigan and along the lake in the vicinity of Holland, Mich., they are destructive to raspberry bushes, strawberries, corn, and grasses." From this and other references in the literature it is evident that the species is more abundant in some places than it is at Manhattan. Saunders (1879) says it is seldom very abundant, but scarcely a season passes without some of them being seen.

Attraction to Lights.—This beetle is apparently more active at night than in the daytime, but during five years collecting only 60 beetles were found at lights. Unlike *Phyllophaga,* individuals of this species do not return to the soil in the daytime, but remain on the food plants apparently inactive and partly hidden in the foliage by drawing a leaf around themselves.

Period of Flight.—The flight period begins, at Manhattan, on an average, about June 1 and lasts until about July 8, with a maximum flight date averaging about June 14. The earliest date on which the beetles were observed flying was May 24 in 1921 and the latest date was July 22 in 1920. The length of the flight in days varied from 21 to 53 days, with an average of 37.4 days. The data relating to the period of flight are shown in Table LXXXIII.

TABLE LXXXIII.—The period of flight of *Cotalpa lanigera.*

FLIGHT.	1917.	1918.	1920.	1921.	1922.	Average.
First flight	June 9	May 26	June 9	May 24	May 25	June 1
Maximum flight	June 19	June 3	June 30	June 10	May 29	June 14
Last flight	June 30	June 25	July 22	July 16	July 4	July 8
Length of flight (days)	21	30	43	53	40	37.4

Food Habits.—Harrington (1890) says that the beetles of this species feed on "various kinds of trees." At Manhattan the beetles were collected on willow and cottonwood. In laboratory cages they fed on elm, poplar, willow, cottonwood, maple, and very sparingly on apple. In 1920 the adults were quite abundant on young cottonwood trees growing on a sandy beach of the Kansas river. Nearly every tree contained beetles, often as many as 10. In all, 92 beetles were found between 10 and 12 a. m. Although willows were abundantly mixed with the cottonwood trees, only one specimen was taken on willow. Two days later 120 beetles were found on the same trees in a period of two hours of an afternoon. On this day, none were found on willows. The beetles were usually in the tops of the young trees and concealed by having pulled the leaves about themselves. Beetles have also been collected on willows at night with the aid of flash lights. Saunders (1879) says the beetles devour the tender leaves of pear, oak, poplar, hickory, silver abele and sweet gum.

Proportion of Sexes.—The males of this species have predominated at lights while the large collections on food plants showed the females to be more abundant. In all of the beetles handled the sex ratio is fairly equal, being 132 males and 148 females. The data are shown in Table LXXXIV.

TABLE LXXXIV.—Proportion of sexes of *Cotalpa lanigera.*

SOURCE.	Males.	Females.	Total.
At lights	22	18	40
On food plants	96	123	219
Reared from collected grubs	6	3	9
Reared from egg	8	4	12
Total	132	148	280

Mating and Oviposition.—The beetles of this species were frequently noted mating on cottonwood trees in the morning and afternoon of days in late June. A male of this species was once noted trying to mate with a male *Pelidnota punctata.*

The first eggs deposited by this species, in rearing cages in 1920 were found on July 3 and the last on July 15, indicating an oviposition period of 12 days. In 1921 the first were found June 20 and the last June 23. In 1922 the first oviposition occurred June 26 and the last July 13, giving a period of 17 days in which eggs were deposited.

Description of Eggs.—The eggs of *Cotalpa lanigera* are pearly-white like other eggs of members of the family. When freshly laid they are elongate-oval and as development proceeds they become more globular.

Length of Egg Stage.—The data on the length of the egg stage are shown in Table LXXXV as obtained during the years 1920, 1921, and 1922. In all, 177 eggs were under observation.

TABLE LXXXV.—The length of the egg stage of *Cotalpa lanigera*.

YEAR.	Number of eggs.	Number of days.		
		Maximum.	Minimum.	Average.
1920	86	27	18	21.8
1921	49	21	18	19.3
1922	42	25	19	21.6
	177	27	18	20.9

It will be observed that the length of the egg stage varied with this species from 18 to 27 days, with an average of 20.9 days. The minimum and average periods were fairly constant for the three seasons. The maximum period was somewhat more variable. The maximum stage of 27 days was noted in 1920.

Description of Larva.—According to Davis (1916) the grubs of *Cotalpa lanigera* are one of the species most likely to be confused with *Phyllophaga* grubs, because they are found in the fields with them and attack the same crops. They can be distinguished, however, by the fact that the ventral surface of the posterior segment of the abdomen lacks the two longitudinal rows of spines, but is covered with thickly placed hooked spines, among which are a few long hairs (Pl. X, fig. 4).

The anal slit is transverse whereas in *Phyllophaga* it is the form of an obtuse angle. The head is tan-colored and the size of the full-grown grub depends on whether it has molted two or three times. As will be pointed out later, some grubs mature after two molts while others require three. Grubs maturing after two molts are about 37 mm. long and 8.2 mm. across the thorax, while the size of the head is from 6 to 6.2 mm. Grubs in the fourth instar, that is, after three molts, are about 43 mm. long and 10.5 mm. wide at the thorax, while the head is about 7.5 mm. wide. The prepupæ close to the time of pupation have greatly shortened, being only about 30 mm. long.

Length of Larval Stage.—Davis (1916) started rearings of these grubs in 1914 and from their size in the fall of 1915 conjectured that the life-cycle would require four or possibly five years for completion. From the data shown in Table LXXXVI it is evident that the beetles require only two or three years in the vicinity of Manhattan to develop from egg to egg.

TABLE LXXXVI.—The length of the larval stage of *Cotalpa lanigera.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Hatching to first molt	49	30	20	23.6
First to second molt	37	326	28	282.8
Second to third molt	5	292	41	143.8
Second molt to prepupa	19	432	66	334.6
Third molt to prepupa	1	379	379	379.0
Active larval stage	21	743	362	542.1
Prepupal stage	22	11	3	6.9
Complete larval stage	18	752	375	558.6

As indicated in this table, the grubs may undergo two or three molts before becoming prepupæ. The data are, therefore, arranged to show the differences in the periods between the second molt and the time of prepupation. The time from hatching to first molt averaged 23.6 days for 49 individuals, and 282.8 days from the first to the second molt, with extremes of 28 and 326 days, which means that some individuals molt the second time during the season in which they hatch and others delay the second molt until the following season. The period from the second to third molt varied from 41 to 292 days, with an average of 143.8 days. In no instance was the third molt observed to occur the first season after hatching, but a sum of the three minimum periods shows it may be possible for the grubs to have their molt 89 days after hatching. The low minimum of 41 days between the second and third molts was noted in cases where the second molt occurred the second season, and the maximum of 292 days is secured in those instances where the second molt occurred the first season and the third molt the second season.

The period between the second molt and the time of becoming prepupa, therefore, depends upon whether or not there is a third molt. In 19 instances where the third molt was absent, the length of the instar varied from 66 to 432 days with an average of 334.6

days. In only one case was the time between the third molt and prepupation noted. This individual had molted twice the first season and the third molt occurred the second summer. There were 379 days between the third molt and prepupa (fourth instar). In all cases (five) where a third molt occurred, the grubs were destined to be three-year grubs. The active larval period varied from 362 to 743 days in 21 cases noted.

The prepupal stage averaged 6.9 days, and ranged from 3 to 11 days, and the complete larval stage, including the active larval stage and prepupal stage, for 18 individuals, varied from 375 to 752 days. If we analyze the periods of the so-called two- and three-year grubs (Table LXXXVII) we get a better representation of the two types of grubs than are given in Table LXXXVI which averages together the periods of the two- and three-year grubs. It would appear from Table LXXXVII that the two-year grubs varied in time of complete development from 375 to 385 days, with an average of 380.3 days; and the three-year grubs required from 725 to 752 days, with an average of 736.8 days. The data on the active larval stages of the two types are also shown in Table LXXXVII.

TABLE LXXXVII.—A comparison of the length of the larval stage of two- and three-year grubs of *Cotalpa lanigera*.

	Two-year grubs.		Three-year grubs.	
Stage	Active.	Complete.	Active.	Complete.
Number of individuals	11	9	10	9
Maximum number of days	380	385	743	752
Minimum number of days	362	375	714	725
Average number of days	373	380.3	728.2	736.8

Food of Grubs.—The grubs in rearing cages were fed grains of wheat, which they ate before and after germination. The grubs collected in nature and reared to adult were collected on the sand dunes of the Kansas river. One was found under dried cow manure and eight were taken in corn land on the sandy dune soil.

Saunders (1879) and Murtfeldt (1901) both record the grubs of this species as injurious to the roots of strawberries. Davis (1918) notes that they are destructive to raspberry bushes, strawberries, corn, and grasses.

Description of Pupa.—The pupa when freshly transformed is a pale yellowish-brown, and the color does not deepen much because

of the light color of the adult. It is about 26 mm. long and 13 mm. wide.

Length of Pupal Stage.—Pupation in the rearing cages occurs in late July and early August. The earliest date noted of its occurrence was July 24, and the latest date August 17. It is quite probable that after emerging from the pupal stage the adults live over winter in the soil before emerging to feed and mate, as is the case with *Phyllophaga* adults. It is on this assumption that the grubs are considered as two- and three-year rather than one- and two-year grubs. If, however, pupation occurs earlier in nature than in rearing cages, there is the probability that the beetles would emerge the same season in which they mature, which is doubtful.

The data on the length of the pupal stage of 12 grubs reared from eggs and 9 grubs collected in the field are shown in Table LXXXVIII.

TABLE LXXXVIII.—The length of the pupal stage of *Cotalpa lanigera.*

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Collected grubs	9	27	24	24.7
Reared from eggs	12	27	23	25.5
	21	27	23	25.1

It will be seen that the average length of the pupal stage is 25.1 days and is fairly constant with a difference of only four days between the minimum and the maximum period.

Life Cycle.—The data on the actual length of the life cycle of *Cotalpa lanigera* for seven two-year grubs and five three-year grubs reared from egg to adult are summarized in Table LXXXIX.

TABLE LXXXIX.—The actual length of life cycle of *Cotalpa lanigera.*

LIFE CYCLE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Two-year	7	432	415	427.8
Three-year	5	797	773	783.4

The data show that the two-year cycle averages 427.8 days, with extremes of 415 and 432 days, while the three-year life cycle varied from 773 to 797 days, with an average of 783.4 lays. It must be

recalled that the period of winter hibernation and inactivity in the spring must be added to the above figures in order to get the total length of time from egg laying to egg laying. This is assuming that the beetles do not fly the same season in which they mature.

If we compute the life cycle from the various figures given in the foregoing data by adding the extremes and averages of the egg, larval, and pupal periods, we arrive at figures such as are shown in Table XC in which the maximum period is found to be 806 days, the minimum 416 days, and the average 604 days.

TABLE XC.—The computed life cycle of *Cotalpa lanigera.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	177	27	18	20.9
Larval	18	752	375	558.6
Pupal	21	27	23	25.1
Total		806	416	604.6

This method indicates a life cycle only nine days longer than in the actual rearings and a minimum period only one day longer, but the averages are quite different because both the two- and three-year larval periods are averaged together.

Summary of the Rutelinæ

It is evident from the foregoing discussion that there are two distinct types of development in the two tribes of the subfamily Rutelinæ. In the Anomalini there appears to be invariably a one-year life cycle, while in the Rutelini it is here shown that at least two years and often three years are needed to complete the life history of two members of the tribe.

In the Anomalini, Hadley (1923) has pointed out that *Popillia japonica* Newm. requires one year to develop. The writer (1918) has shown that *Anomala binotata* Gyll. matures in one season. The larvæ requiring, on an average, 83 days to develop, and pupation occurs in the fall. On the contrary, *Anomala innubia* normally matures in the spring, but only requires one year to complete growth. Two instances were noted wherein the larvæ of *A. innubia* pupated in December. The writer has reared a new species, *Anomala Kansana,* H. and McC., whose life cycle is quite similar to that of

A. innubia. It has also been shown (Hayes, 1921) that *Strigoderma arboricola* Fab., another Anomalini, has a one-year life cycle in which development is completed in from 351 to 358 days. In this case the larvæ pass the winter and pupation occurs in the spring.

Pelidnota punctata requires two years to mature, while *Cotalpa lanigera* needs either two or three years to finish growth.

The Life History of the Dynastinæ

This subfamily is remarkable for the fact that it contains some of the largest coleopterous insects. One has only to recall such genera as *Dynastes* and *Strategus* to realize this fact. The group contains a number of species whose depredations on crops make them of considerable economic importance, especially in the southern part of the United States and in the West Indies. One species, *Ochrosidia immaculata* Burm. (*Cyclocephala*) is very injurious in the larval stage to the roots of staple crops in the central states and another *Ligyrus gibbosus* DeGeer, known as the carrot-beetle or muck-worm, is destructive in the adult stage to carrots, sunflowers and other plants. Of these two, both have been under observation during the course of this study. *Ochrosidia immaculata* has been reported under the name of *Cyclocephala villosa* (Hayes, 1918) and the life cycle was given as one year. Likewise *Ligyrus gibbosus* was found (Hayes, 1917) to have a one-year life cycle. *Ochrosidia* differs from *Ligyrus,* in passing the winter as a larva and maturing in the spring, while *Ligyrus* matures the same summer or early fall in which it hatches and hibernates as an adult.

Smyth (1916) has reported on the period of development of five species representing three genera of this subfamily. He found that *Strategus titanus* Fab. in Porto Rico required an average of 338 days to reach maturity, *Strategus quadrifovatus* Beauv. required slightly over one year to develop and *Ligyrus tumulosus* needed only 77 days. Two other species, *Dyscinetus barbatus* complete their growth in 104 and 144 days, respectively. Phillips and Fox (1917) report the development of *Euethola rugiceps* in about 88 days.

The only species considered in detail in this paper, *Ligyrodes relictus* Say (*Ligyrus*), is to be regarded as a benficial species, living as it does in manure and rotting haystacks and thus materially hastening the processes of decomposition. Smith (1902) reported the beetles injuring the roots of hardy pyrethrums and the roots of sunflowers, but his statement that the species is smaller than the ordinary June-bug and more roughly sculptured, leads to the

suspicion that his determination was incorrect. These two characters and the habit of attacking sunflowers would suggest that *Ligyrus gibbosus* DeG. was the species in question. Smith appears to be the only writer who considers *Ligyrodes relictus* as an injurious species. There are no citations in the literature treating of the life history of the species and scarcely any habits are mentioned except that the beetles and grubs live in decaying vegetable matter.

LIGYRODES RELICTUS SAY

Ligyrodes relictus (Pl. II, fig. 2) was described by Say in 1825 as *Scarabœus relictus* from specimens collected in Pennsylvania and Massachusetts. In 1847, Burmeister created the new genus *Ligyrus* to contain *L. fossator* and others, but at that time considered *relictus* in the genus *Heteronychus*. It was once erroneously cited in *Bothynus* and finally placed in *Ligyrus* where it remained until 1915, when Casey created the new genus *Ligyrodes*. It is by the name *Ligyrus relictus* that the species is best known. Casey on the basis of the quite distinct shape of the body; the transverse, slit-like anterior, abdominal spiracles; the nude apex of the post-coxal prosternal process; and the sexual modification of the anterior tarsi of the male which indicates relationship to the Cyclocephalini, used this species as the type of *Ligyrodes*. This has been accepted and is the name used for the species in Leng's catalogue.

For the sake of reference and to make it more accessible, the original description (Say, 1825) with the describer's remarks concerning it are here quoted:

"*S. relictus*—Head with an elevated transverse line, interrupted in the middle; clypeus at tip elevated and bidentate.

"Body brownish-black; head with a transverse elevated line between the origin of the antennæ, interrupted in the middle, and most prominent near the interrupted part; tip of the clypeus with two reflected, acute denticulations: thorax with rather sparse punctures: elytra punctured, and with three double series of punctures, converging towards the apical angle; the second and third double series do not reach the angle, a fourth double series is on the exterior submargin, but is not so distinct as the other: beneath piceous: pectus and post-pectus hairy; feet above blackish; venter blackish. Length more than four-fifths of an inch.

"It may be compared with the *S. punctatus* Fab. of southern Europe, but is of a more slender form and is otherwise distinguished by the armature of the anterior termination of the head. I have found specimens in Pennsylvania. It varies in having the reflected tip of the head emarginate, and not deeply divided into teeth. I have received a specimen from Dr. T. W. Harris of Milton, Massachusetts."

Distribution.—According to Casey (1915) the species is common from Rhode Island to Iowa. Leng (1920) in his catalogue gives a questionable reference from Florida. As noted above, Say had a specimen from Massachusetts. The collection of the Kansas State Agricultural College has specimens from Manhattan, Dodge City, Medora, Junction City, and El Dorado. Specimens in the Cornell collection are from Ithaca, N. Y., Iowa City, Iowa, and Elmhurst, Long Island. The beetles have been noted as being distributed by streams after heavy rain (Hayes and McColloch, 1922).

Abundance.—The collections in the present study for the years 1916 to 1922 at Manhattan indicate that the species is not as well represented as the *Phyllophaga*. Since the beetles feed on decaying matter in the soil and are not found on food plants, they are found above ground only at night when they appear at lights. The numbers collected at lights give the only indication obtainable of their abundance. Table XCI shows the numbers collected at lights, in the soil, and those reared during the present study.

TABLE XCI.—The relative abundance of *Ligyrus relictus*.

SOURCE.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	Total.
At lights	29	35	17	0	46	80	27	234
Miscellaneous	4	0	0	1	0	1	0	6
Reared from collected grubs	12	0	11	12	1	63	6	105
Reared from eggs	0	0	0	0	0	1	0	1
Total	45	35	28	13	47	145	33	346

A total of 234 beetles were taken at lights, 105 were reared to maturity in the insectary from grubs collected in nature, one from the egg, and six from miscellaneous sources, making a total of 346 beetles that were handled during the seven-year period. None of these beetles were found at lights in 1919, and other species were proportionately scarce.

Attraction to Lights.—This species has two distinct periods of flight during which the beetles appear at lights. (Fig. 1.) These may be considered as the spring and summer flights. As the beetles feed on decaying vegetable matter, they are never found on food plants. The purpose of the flight to lights is somewhat of a mystery. It is not a mating flight for, as will be noted later, mating occurs beneath the surface of the soil after or during the time of the spring flight.

Period of Flight.—The spring flight may commence as early as April 23, as it did in 1917, or as late as May 17 as in 1918. The flights lasts from 33 to 66 days, with a six-year average of 52 days. There is an interval which may vary from 14 to 53 days between the cessation of the spring flight and the summer flight which begins in late July or early August, and may last 55 days. The six-year average of the summer flight was 40 days. Davis (1916) states that the beetles appear at lights almost the whole season through due to the overlapping of the broods. The beetles appearing in the spring flight are those of the overwintering brood. They lay their eggs and die and their progeny develop during the summer and appear above ground during the summer flight. Table XCII gives the pertinent data concerning the flight periods during the period of observation which are also represented graphically in figure 1.

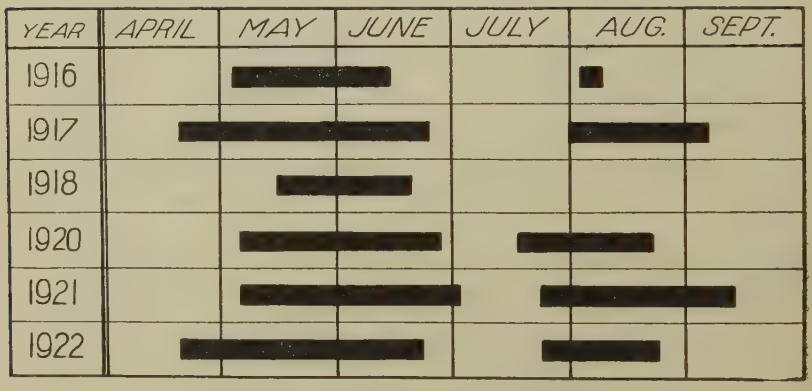

FIG. 1.—The flight periods of *Ligyrodes relictus* Say.

Soil Preferences.—The present study gave only a faint indication of the soil preference of the beetles. They were found under rocks in high upland prairie situations and in lawns. Blatchley (1910) states that the beetles have been commonly found in northern Indiana on the sandy lake shores. Several grubs were collected under animal droppings on the sand dunes in the region of Manhattan. These observations suggest that the beetles may be found wherever decaying organic matter may be abundant, with perhaps a slight preference for sandy soils.

Food Habits.—Two beetles were found feeding on the roots of an aquatic grass plant on the shore of a small lake near McPherson, Kan. Efforts to induce them to feed in rearing cages proved futile.

TABLE XCII.—The period of flight of *Ligyrodes relictus*.

FLIGHT.		1916.	1917.	1918.	1920.	1921.	1922.	Average (days).
Spring flight	First appearance	May 4	April 23	May 17	May 4	May 5	April 25	.....
	Last appearance	June 11	June 28	June 19	June 29	July 2	June 26	.....
	Length of flight; days	38	66	33	56	58	62	52
Interval between flights		53	34	.....	14	19	30	.....
Summer flight	First appearance	Aug. 3	Aug. 1	.....	July 13	July 21	July 26	.....
	Last appearance	.....	Sept. 6	.....	Aug. 24	Sept. 14	Aug. 22	.....
	Length of flight; days	.....	36	.....	42	55	27	40

During these studies, grubs have been found and subsequently reared to maturity in horse and cow manure, in rotten straw, in the soil of an oat field quite rich in humus, and in old decaying haystacks.

Proportion of Sexes.—The relative number of males and females collected during this work is scarcely large enough to draw conclusions as to the proportion of sexes found in nature. Table XCIII shows the proportions observed since 1917. The sexes were not noted in the 1916 collection, but the table includes 12 specimens reared from collected grubs that year.

TABLE XCIII.—The proportion of sexes of *Ligrodes relictus.*

SOURCE.	Males.	Females.	Total.
At lights	120	85	205
Miscellaneous	0	2	2
Reared from grub	49	51	100
Reared from egg	1	0	1

As in the case of many other insects, the males predominated in the light collections but were about equal in numbers to the females in the specimens reared from grubs. The collections at lights and miscellaneous situations are indicated by years in Table XCIV. Here it will be seen that in some years the males predominated, while at other times the females were more abundant, the total for the six years favoring the males.

TABLE XCIV.—The proportion of sexes of *Ligyrodes relictus* by years.

SEX.	1917.	1918.	1919.	1920.	1921.	1922.	Total.
Males	18	7	0	18	55	22	120
Females	17	10	1	28	26	5	87
Total	35	17	1	46	81	27	207

Mating.—In contrast to other species herein discussed, this species as well as its allied species, *Ligyrus gibbosus,* mate beneath the surface of the soil. Davis (1916) noted this fact and the writer has since found *Ligyrodes relictus* mating under four inches of manure and frequently in the soil at varying depths in rearing cages.

Description of the Egg.—The eggs of *L. relictus* are pearly-white in color, and when freshly laid are elongate-oval in form and

about 2.5 mm. long and 2 mm. wide. As development proceeds there is an increase in size and a gradual change in shape until the eggs are almost spherical. When growth is complete they are about 3.1 mm. long and 2.9 mm. wide. The eggs are laid singly in the soil and in one instance, in a rearing cage, an egg was found in the center of a small ball of dirt as is the general rule in *Phyllophaga*. Since the eggs cannot be distinguished from the eggs of other related species in nature, none were observed except in rearing cages, and it may be that under normal conditions the eggs are all laid in small earthen balls. No data are available of the number of eggs laid by individual females.

Period of Oviposition.—Eggs are deposited by the females during the latter part of May and throughout June, or during the period of the spring flight. After the first beetles appear at lights there is a preoviposition period of four to five weeks before eggs are found in life history cages. The dates on which the first eggs were found in rearing cages and the dates of first hatching are given in Table XCV.

TABLE XCV.—The date of first oviposition and first hatching of *Ligyrodes relictus*.

	1916.	1917.	1919.	1920.	1921.	1922.
First oviposition	June 19	June 13	June 11	June 10	June 17	May 31
First hatching	June 28	June 26	June 16	.....	June 23	June 6

Length of Egg Stage.—The data relating to the length of the period of development are meagre, since the exact period was determined in only four instances. The data secured are shown in Table XCVI.

TABLE XCVI.—The length of the egg stage of *Ligyrodes relictus*.

DATE LAID.	Date hatched.	Length of stage (days).
June 19, 1916	June 28, 1916	9
June 17, 1921	June 25, 1921	8
June 17, 1921	June 28, 1921	11
June 20, 1921	June 29, 1921	9
Average		9.3

In 1917, two eggs laid before June 19 hatched June 26, seven days after being found. In 1919, nine eggs laid before June 11 hatched from 5 to 10 days later. Four of these required ten, and two, nine days. Of a number of eggs laid in 1922 at uncertain dates, three hatched in six days; one, in nine days; two, in ten days; and five, twelve days after they were found. From these data it may be suspected that the average of 9.3 days given in the table is somewhat shorter than the true period of hatching.

Description of Larva.—Full grown larvæ are about 36 mm. long and 9 mm. wide. They are relatively large with small heads which are dark brown in color and with a surface rather strongly reticulate. The posterior segments of the abdomen are quite characteristic in being somewhat enlarged. The ventral surface of the anal segment (Pl. X, fig. 7) is described by Davis (1916) as bearing "a patch of sparsely and irregularly placed short spines intermixed with a few longer hairs, and the dorsal surface of this segment bears only a few short spines and hairs." There is no medial longitudinal row of spines.

Food of the Grubs.—Grubs reared in soil containing grains of wheat were frequently observed feeding on the kernels before they had sprouted. One specimen was taken in an oat field where it had developed either on the roots, fallen kernels, or decaying vegetable matter. Grubs are frequently encountered in the lower, rotting parts of old haystacks, but more often under cow and horse manure in pastures and meadows where they thrive on the decaying matter.

Length of Larval Stage.—Because of the specialized type of environment required by this species, the rearing of the larva is extremely difficult. Only one individual was reared to maturity under the artificial conditions of the cave and insectary. Hence, only meagre data are available on the active larval stage which in this case was 46 days from hatching, June 25, 1921, to the prepupal stage, August 10, 1921. Five more days were needed for the prepupal period, making a total larval period of 51 days. It was observed to molt twice. The first instar was 17 days in length, the second 4, the third 25, or a total period of 46 days. The most active feeding stage is between the first and second molt, and development is, therefore, most rapid during this period.

The grubs collected in the field, especially those nearly full grown, can more easily be reared to maturity under artificial conditions, and hence the data on the inactive larval or prepupal period are more

comprehensive. Seventy-seven such grubs were reared through the prepupal stage in addition to one reared from the egg. The length of the prepupal stage for these is shown in Table XCVII.

TABLE XCVII.—The length of the prepupal stage of *Ligyrodes relictus*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared grub	1	5	5	5.0
Collected grubs	77	21	1	4.0
	78	21	1	4.09

The average pupal period for the 78 grubs was 4.09 days, with a maximum of 21 and a minimum period of one day. Seven instances were noted in which the prepupal stage required but one day. In each instance observation was made in July, which suggests that the rapid development may have been due to the heat of midsummer.

Description of Pupa.—The pupa of *L. relictus* is 21 mm. long and 14 to 15 mm. wide. When freshly transformed it is creamy white in color, changing though a pale yellow to brown. Just before emergence, the dark color of the beetle can be seen through the integument. The anal processes present in the pupa of *Phyllophaga* are absent. Otherwise, there is considerable similarity.

Length of Pupal Stage.—The length of the pupal period was observed for 100 grubs, collected and reared during the period from 1916 to 1922, inclusive. The record includes also one grub reared from the egg. Table XCVIII shows the maximum, minimum, and average period of these pupæ.

TABLE XCVIII.—The length of the pupal stage of *Ligyrodes relictus*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared from egg	1	11	11	11
Reared from collected grubs	100	26	9	13.1
	101	26	9	13.1

The shortest pupal period observed was nine days and the longest 26 days, with an average of slightly over 13 days for 101 individuals. The time of pupation was found to vary considerably in

the different years. In 1916, the earliest specimen pupated on July 14, in 1918 on June 24, in 1919 on July 2, in 1920 on August 16, in 1921 on June 27, and in 1922 on July 8. It is probably safe to say that in nature pupation begins the latter part of June or in early July in normal seasons.

Life Cycle.—The average periods of development of the different stages has been found to be: for the egg stage, 9.3 days; the active larval period, 46 days; the prepupal period, 4.09 days; the pupal period, 13.1 days, or a total of 72.4 days for full development. A single specimen reared from the egg required 70 days for complete development, thus approximating very closely the full period computed from the length of the different stages.

Davis (1916) has reported that the species develops in one year, but gives no data on the length of stages. The beetles appear above ground in April or May for the spring flight, returning to the soil each day, where mating occurs. They disappear for a short time in June and July and the new brood appears in July and August for a second period of flight.

Summary of the Dynastinæ

Table XCIX has been compiled to show the life history of various numbers of the Dynastinæ as shown by the work of Smyth, Phillips, and Fox in comparison with the data secured in the present study. It will be observed that all species discussed have a one-year life cycle with the exception of *Strategus quadrifoviatus*, which is only slightly in excess of one year. However, some have a longer larval period than others, and in such cases nearly the full year is required to complete development.

The Life History of the Cetoniinæ

Several members of the subfamily Cetoniinæ are injurious to vegetation in the United States. Chief among these are the Bumble flower-beetle, *Euphoria inda* Linn. and the Green June-beetle or Fig-eater, *Cotinus nitidia* Linn. As a rule, the mandibles of the adults of this subfamily are poorly developed and are fitted only for the eating of such light foods as pollen and sap.

There is very little American literature on the life history of American species of this group. *Euphoria inda* is commonly assumed, and probably correctly, to have a one-year life-cycle, and the Green June-beetle, *Cotinus nitidia*, has been reported by Chittenden and Fink (1922) to have a one-year period of development.

TABLE XCIX—A comparison of the life cycle of various members of the *Dynastinæ*.

SPECIES.	Egg stage.			Larval stage.			Pupal stage.			Egg to adult.
	Average.	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Ligyrodes relictus	9	11	8	50	.....	.....	13	26	9	72
Ligyrus tumulosus	13	.....	.....	55	.....	.....	14	.....	.....	77
Ligyrus gibbosus	10	22	7	59	80	43	19	29	11	88
Ochrosidia immaculata	15	25	13	347	384	335	17	21	15	379
Strategus titanus	17	21	15	344	.....	.....	23	24	.....	338
Strategus quadrifovatus	20	.....	.....	385	.....	.....	27	.....	.....	430
Dyscinetus trachypygus	12	18	10	81	.....	.....	13	16	12	104
Dyscinetus barbatus	13	.....	.....	106	.....	.....	15	18	13	144
Euetheola rugiceps	14	.....	.....	60	.....	.....	14	.....	.....	88

In the present study, a number of species have been under observation, such as *Euphoria inda, Trichius piger, Osmoderma eremicola,* and *Cremastochelius nitens.* The life-cycle of none of these has been completely worked out, but two species, *Euphoria fulgida* and *Euphoria sepulchralis,* have been carried through to maturity and the results are here set forth.

EUPHORIA FULGIDA FABRICIUS

Description and Synonymy.—This species (Pl. II, fig. 3) was originally described by Fabricius (1775) in the genus *Cetonia* as follows:

"C. ænea nitidissima, abdominis ultimo segmento prominente quadripunctato. Habitat — . . . Minor pracedenti. Capitis clypeus integer. Thorax æneus parum ferrugineo mixtus, nitidissimus. Scutellum triangulare breve. Elytra vividia nitida ferrugineo mixta postice gibba. Sternum breve apice rotundatum. Abdomen æneum utrinque lineis duabus macularum albidarum. Ultimum segmentum prominet punctis quatuor albis. Anus rufus. Pedes testacei geniculis nigris."

A description in English by Blatchley (1910) follows:

"Oblong-oval. Head and thorax usually brilliant green, the latter margined at the sides with yellow; elytra green, usually with a reddish-brown tinge, sometimes marked with chalk-white spots; abdomen green, the sides with whitish spots; pygidium with four similar spots on base; legs reddish or brownish-yellow, tinged with green. Entire upper surface sparsely and rather finely punctate; elytra with only faint traces of costæ. Length, 13-18 mm."

The males may be distinguished from the females by the presence of a dark stripe on the ventral abdominal segments.

In 1842, Burmeister placed this species in the genus *Erirhipis.* At the same time he created the genus *Euphoria* for other species. Lacordaire assigned all of the present tribe Cetoniini to the genus *Euryomia* with the statement that *Euphoria* was only a name for a special zoölogical region, and it remained for Horn to reinstate the genus *Euphoria* as we now know it.

Distribution. — *Euphoria fulgida* is apparently distributed throughout most of the United States east of the Rocky mountains. Casey (1915) has recorded it in Michigan, Kansas, and Texas, while Leng (1920) cites Connecticut, Michigan, and Indiana as limits of the area in which it is found. Davis and Luginbill (1921) state that the distribution of *E. fulgida* is the same as that of *Cotinus nitidia* whose range is said by them to be, in general, east of the Mississippi river and south of latitude 29 degrees, or as far north

as St. Louis and Cincinnati in the Mississippi and Ohio valleys, and somewhat farther north along the Atlantic coast. They also state that the farthest north record is one by Bowditch (Psyche, vol. 7, p. 8) from the summit of Mount Washington.

Specimens are in the Cornell collection from Arizona, Douglas county, Kansas, Las Vegas, N. M., Ithaca and Middletown, N. Y., Georgia, Chapel Hill, N. C., and Toronto, Ontario.

Relative Abundance.—The beetles of this species have not been very abundant in the vicinity of Manhattan during three years in which it was under observation. It has been collected only on food plants and in flight. Table C shows the numbers collected during the years 1920 to 1922:

TABLE C.—The relative abundance of *Euphoria fulgida* at Manhattan.

SOURCE.	1920.	1921.	1922.	Total.
Food plants	19	110	3	132
In soil	2	0	0	2
Flying	0	1	1	2
Reared from eggs	0	0	4	4
Total	21	111	8	140

Attraction to Lights. — This species is apparently never attracted to lights. It is day flying in habits and was never found at lights among other beetles collected during the progress of this work.

Period of Flight.—The length of the period of flight has varied somewhat during the three seasons in which it has been recorded. In 1922, only 15 days intervened between the first and last flight, while in 1920 the period of flight was 59 days—May 21 to July 25. These data with the average periods of flight are shown in Table CI. It may be mentioned that the beetles are strong fliers and not easily collected in flight.

TABLE CI.—The period of flight of *Euphoria fulgida*.

FLIGHT.	1920.	1921.	1922.	Average.
First flight	May 28	May 21	June 10	May 31
Last flight	July 25	June 21	June 24	July 8
Length of flight; days	59	32	15	39

Soil Preferences of Adults.—Very little data are available on the soil preferences of the beetles of *Euphoria fulgida*. Only two were collected in the soil. These were found on a stony hillside under oak and dogwood with which the hillside was overgrown.

Food Habits.—As mentioned before, the mandibles of this and other species of Cetoniinæ are poorly developed and fitted for feeding on such food only as pollen and sap of plants. All but four of the 140 beetles collected during the three years were found feeding either on the sap of trees or the pollen of plants. Of 21 beetles found in 1920, 15 were feeding on the sap exuding from wounds of oak trees, one was taken on willow at night, another on walnut, and still another in moss at the base of an old stump. The collections in 1921 were larger, and of these five were found on a wound on a stalk of thistle, 70 on blossoms of thistle, four on blossoms of dogwood, three on blossoms of sumac, six on a wound on an exposed root of oak, six were feeding on sap from the broken limb of an oak, seven were feeding on the sap of the stump of an oak, and eight were at a wound on the trunk of an oak. In 1922, the beetles were found only on the wound of an oak tree.

It is reasonable to suppose that the beetles were feeding on pollen when taken on blossoms and it is evident that thistle blossoms are preferred. Sap of thistle and oak are relished, and from the numbers taken on oak it is apparent that this sap is rather attractive to them. The beetles are often found on blossoms in company with *Euphoria inda* and *Euphoria sepulchralis*. Lintner (1891) records the beetle as having been found on a cherry tree by one of his correspondents.

Proportion of Sexes.—In only a few instances were the sexes noted and the numbers are not sufficient to consider sex ratios.

Mating and Oviposition.—The beetles were not observed mating in the fields, but mating probably occurs on the blossoms of food plants.

Description of Eggs.—The eggs of this species are about 1.8 mm. long and 1.3 mm. wide, when freshly laid. They are elongate-oval and enlarge slightly during development until a more globular form is assumed. Eggs laid in the ground and in rearing cages were always found singly. They are pearly-white in color.

Length of Egg Stage.—The first eggs were hatched June 20 and the last July 7. The average length of the egg stage for 140 eggs was 10.7 days, with a minimum of 8 days and a maximum of 13 days.

Description of Larva.—The grubs of this species exhibit the peculiar habit of crawling on their back. This is also characteristic of other species of the genus *Euphoria* and also occurs in the genus *Cotinus*. Just before pupation they prepare an earthen ball cemented together by secretions from the larva, in which the pupal period is passed. The larvæ have a transverse anal slit and the last segment bears on its ventral surface two rows of spines arranged longitudinally. These spines are much stouter than those of *Phyllophaga* grubs.

Davis and Luginbill (1921) describe the larva of *E. fulgida* as follows:

"Grubs of the flower beetles (*Euphoria fulgida* Fab. et spp.) closely resemble the *Cotinus* grubs, in that they crawl on their backs, but are distinguished by their smaller size when full grown, and the under surface of the anal segment is not uniformly clothed with hairs, the remainder of the ventral segment being bare; furthermore, spines in the two median longitudinal rows are directed or inclined inwardly and are not so thick or stout as in *Cotinus*."

Length of Larval Stage.—The length of the active larval stage was observed in 51 larvæ, but the length of the prepupal stage was noted in only five instances. This difference is due to the fact that this species has an exceptionally long prepupal stage in which it passes the winter, a habit not noted in any other scarabæid under observation. Because of the long prepupal period a heavy rate of mortality is experienced between the beginning of the prepupal stage and the time of pupation. The dates of molting and the length of the various instars were not noted with this species. The data on the length of the larval stage are shown in Table CII.

TABLE CII.—The length of the larval stage of *Euphoria fulgida*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Active larval	51	156	98	122.0
Prepupal	5	240	198	227.4

It was found that the active larval stage varied from 98 to 156 days, with an average of 122 days. The larvæ begin the prepupal stage in late September, in October, or as late as the last of November in the rearing cages, and the period of hibernation is passed in the prepupal condition. The five individuals which successfully survived the winter began to pupate June 10 and all had become pupæ by June 16.

It will be noted that the prepupal stage varied from 198 to 240 days with an average of 227.4 days for the five individuals reared.

Food of the Grubs.—The food of the grubs of *Euphoria fulgida* has not been noted in nature as no grubs have been collected and reared to adults. It is next to impossible to observe feeding in nature because of the difficulty in distinguishing the grubs. In rearing, it was assumed that manure and decaying organic matter were the normal foods, because such materials are known to be food for *Euphoria inda*. The larvæ thrived on manure in the cages until September 6 when, by mistake, they were fed ungerminated wheat grains. They ate this readily and little was left of it in the cage when changed and fed one week later.

Length of Pupæ Stage.—As noted above, pupation in the rearing cages occurs in June, but probably somewhat earlier in nature since the beetles have been collected as early as May 21. They evidently fly, mate, and lay eggs soon after becoming adult. The length of the pupal stage is shown in Table CIII, in which it is seen that the range of the four individuals was from 19 to 25 days, with an average of 21.2 days.

TABLE CIII.—The length of the pupal stage of *Euphoria fulgida*.

DATE PUPATED.	Date adult.	Length of stage (days).
June 10	June 30	20
June 12	July 3	21
June 16	July 11	25
June 16	July 5	19
Average		21.2

Life Cycle.—The length of the life cycles of the four beetles reared from eggs to adults is shown in Table CIV.

TABLE CIV.—The life cycle of four individuals of *Euphoria fulgida*.

Egg stage.	Active larva.	Prepupa.	Pupa.	Total.
Days. 9	*Days.* 119	*Days.* 240	*Days.* 25	*Days.* 393
10	116	240	19	385
10	126	219	20	375
12	145	198	21	376

It will be seen that the four individuals varied in the period required for complete development from 375 to 393 days. This period is practically the same as the complete life cycle, as the beetles fly soon after developing from the pupa.

The life cycle as computed from the average, maximum, and minimum periods of growth is shown in Table CV. These figures indicate a maximum of 434 days for complete development and a minimum of 323 days. The maximum is almost a month longer than the maximum observed for the reared beetles, and the minimum is nearly two months shorter than the minimum observed for the reared beetles.

TABLE CV.—The computed life cycle of *Euphoria fulgida.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	140	13	8	10.7
Active larva	51	156	98	122.0
Prepupa	5	240	198	227.4
Pupa	4	25	19	21.2
Totals		434	323	381.3

The results of the life history studies observed in Kansas are not in accord with those of Davis and Luginbill (1921) who state that "*Euphoria fulgida* is likely to be confused with *nitidia,* and also its distribution is similar. However, its life history is different in that the beetles appear in September, pass the winter in the adult stage, and reappear in spring, at which time the eggs are laid. By the time the beetles of *nitidia* appear, those of *E. fulgida* have disappeared."

EUPHORIA SEPULCHRALIS FABRICIUS

Description and Synonymy. *Euphoria sepulchralis* (Pl. II, fig. 4) was described in 1801 by Fabricius in the genus *Cetonia* as follows:

"C. clypes reflexo, integro, tomentosa, fusca elytris albomaculatis. Habitat in Carolina. Statura et magnitudo omnino C. sticticæ at omnino distincta. Clypeus reflexus, integer. Caput et thorax tomentosa, fusca, immaculata. Elytra substriata, fusca albo obscuro maculata. Abdomen obscure æneo-nitidulum, aliquot albis, lateralibus."

Burmeister (1842) established the genus *Euphoria* with *E. sephulchralis* as the type. *Cetonia reichii* Gory and Percheron has been shown to be a synonym of *E. sepulchralis* by Burmeister. The status of the genus *Euphoria* was considered in doubt by some writers but was restored to standing by Horn (1880).

The beetle is one that is easily confused with *Euphoria melancholica* Horn and is described by Blatchley (1910) as follows:

"Oblong-oval, beneath, bronzed, shining, with a violaceous tinge; above, dark brownish-bronze, feebly shining; elytra with numerous short, sinuous transverse, whitish lines. Thorax triangular, base emarginate at middle; surface coarsely punctured, more densely on sides, clothed with short, erect, persistent pubescence. Elytra each with two costæ; intervals with numerous coarse punctures, these changing on sides to short, deep transverse wrinkles; tips subtruncate, distinctly sinuous. Pro- and mesosterna, femora and sides of abdomen hairy. Length, 9-13 mm."

Distribution.—This species is apparently widely distributed over the southern states as far north as the latitude of Indiana. Casey (1915) cites Texas, southern Louisiana, and St. Louis, Mo., as locality records and Long (1920) gives Texas, Louisiana, Indiana, Missouri, and Florida. In the Cornell collection there are examples from North Carolina; Billy's Island in Okefenokee Swamp, Ga.; Fort Reed, Fla.; Morgan City, La.; and Douglasville, Forsythe, and Commerce, Ga. In Kansas, specimens were taken in Riley county.

Relative Abundance.—During four seasons in which collections have been made, only 101 beetles have been taken on food plants, and one was taken in flight. Six have been reared from grubs collected in the field, and 24 have been reared from eggs. The abundance of this species at Manhattan, as shown by collections during four years, is indicated in Table CVI.

TABLE CVI.—The relative abundance of *Euphoria sepulchralis* at Manhattan, Kan.

SOURCE.	1917.	1920.	1921.	1922.	Total.
Food plants	58	4	35	4	101
Flying	0	0	1	0	1
Reared from grubs	0	0	6	0	6
Reared from eggs	0	0	24	0	24
Total	58	4	66	4	132

This species is frequently found on plants in various parts of the country and is considered one of the "flower beetles" as are other

species of *Euphoria*. Weed (1895) has given it the name "Euphoria corn beetle" after finding it on corn in Mississippi. It is not of great economic importance, but has occasionally been reported injuring plants by sucking the sap at wounds.

Attraction to Lights.—This beetle has not been reported in the literature as attracted to lights nor was it found at lights during these studies. It is diurnal in habits and its presence at lights would be unexpected.

Period of Flight.—There are normally two flight periods in one season for this species. The beetles mature in September and October and appear above soil soon afterwards, where they are to be found on late-blooming flowers. By the time of the first frost they return to the soil to hibernate. It was not observed whether the beetles return daily to the soil as do many other Scarabæidæ, especially *Phyllophaga,* and it is doubtful if they do. In late May and early June the adults come above the surface of the soil for their mating flight, soon after which eggs are deposited.

In this study the autumn flight only was observed in 1917 in which beetles were found from September 22 to October 4. In 1920 the second flight only was noted in which beetles were taken from September 4 to September 20. Both the spring and fall flights were noted in 1921, the former occurred from May 20 to June 15 and the fall flight from August 17 to August 31. The spring flight in 1922 was from June 6 to June 15. These data show that the flight periods are relatively short and the spring flight may occur as early as May 20 and as late as June 15, while the autumn flight may occur as early as August 17 or as late as October 4.

Soil Preferences of Adults.—The beetles develop in manure and other decaying organic matter, and soils rich in such substances are naturally preferred. The character of the soil itself should have no influence on development if the organic matter is present. From six grubs collected in the fields and reared to maturity, the data show that the beetles develop under dung on high upland prairie pastures and on low, sandy dune soils of the river valley.

Food Habits.—Like *E. fulgida,* this beetle has poorly developed mouthparts and feeds on either pollen or nectar and sap flowing from the wounds of plants. Chittenden and Fink (1922) believe that *E. sepulchralis* makes the wounds in plants, for they report *Cotinus nitida* feeding on sap at wounds made by *E. sepulchralis* on the tip of an ear of corn.

Forbes (1905) cites this species as feeding on corn, and Weed

(1895) states that it is found on the inner side of the leaves near their juncture with the stalk where they eat the sweetened moisture and in autumn are found on the ears of corn. Popenoe (1917) has found the beetle with regularity on the blossom of mango where he suggests they play a role in the pollination of the plant. Jones (1918) has captured the beetle under conditions indicating that it was attacking artichokes, and Glover (1878) has figured the beetle with a notation that it frequents cotton plants for the nectar and sap.

In the studies at Manhattan, the beetles have been found on the blossoms of milkweed, thistle, dogwood, and sumac, and at a wound made in the stock of a thistle plant in company with five *Euphoria fulgida* and one *Euphoria inda*. In rearing cages, beetles were attracted to poison bran mash.

Proportion of Sexes.—The sexes are somewhat difficult to distinguish and no notation was made of the proportion of each.

Mating and Oviposition.—Mating has not been observed in these studies. It probably occurs during the spring flight, for it seems hardly probable that it would occur during the autumn flight.

During 1921, eggs were laid in insectary cages from May 27 to June 24. They were laid singly in soil richly covered with manure. One female deposited 25 eggs in a cage in the insectary from June 13 to June 27 at intervals of two to three days apart, ranging from one to seven each time they were found. In nature, although not observed, eggs are probably laid on the soil under dung and other decaying organic matter.

Description of Eggs.—The eggs are pearly-white in color and oblong-oval in shape when freshly laid, at which time they are about 2 mm. long and 1.5 mm. wide. They become more spherical and slightly larger when further developed.

Length of Egg Stage.—The length of the egg stage was noted for 27 eggs in 1921. The average period was 11.8 days, with a minimum period of 9 days and a maximum period of 13 days.

Description of Larva.—The larvæ of this species closely resemble those of *E. fulgida,* and like them crawl on their backs and when near pupation construct an earthen cell in which to pupate.

Length of Larval Stage.—The periods of the various instars of the larval stage were not noted. Molting occurs twice during development. The active larval stage was noted in only 10 instances of the 25 reared to pupation, because the time of assuming the pre-

pupal condition was overlooked. Accordingly, the prepupal stage was noted in ten of these individuals only, but the data are augmented by the addition of four records of the prepupal stage of grubs collected in nature and reared to adult. The length of the various stages are shown in Table CVII.

TABLE CVII.—The length of the larval stage of *Euphoria sepulchralis*.

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Active larva	10	79	53	62.7
Prepupa	14	13	5	7.5
Complete larva	25	87	56	65.7

It should be observed that the active larval stage varied from 53 to 79 days, with an average of 62.7 days, and the prepupal stage from 5 to 13 days, with an average of 7.5 days. The complete larval stage, including the active and the prepupal stages, averaged 65.7 days, with extremes of 56 and 87 days.

Food of the Grubs.—The only hint as to the food habits of the larvæ is to be had in the rearing of six individuals from grubs collected under manure on the sand dunes and prairie pastures near Manhattan.

Length of Pupal Stage.—Pupation occurs in an earthen cell made by the larva. This cell is formed of particles of soil cemented together by a secretion of the larva and is about 14 mm. long and 10 mm. wide. Pupation began in 1921, on August 22, and continued until September 30. Also, in 1922, it was observed in August and September. Data are available on the pupal period of 6 specimens reared from grubs and 24 individuals reared from eggs. These data are shown in Table CVIII in which it will be noted that the minimum period was 9 days and the maximum period was 23 days. The average of the 30 observations was 15.4 days.

TABLE CVIII.—The length of the pupal stage of *Euphoria sepulchralis*.

SOURCE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Reared from grubs	6	23	9	12.3
Reared from eggs	24	23	11	16.2
	30	23	9	15.4

Life Cycle.—Twenty-four specimens of *Euphoria sepulchralis* were reared from egg to adult. Egg laying occurs after a mating flight in May and June and the beetles become mature by September. At this time a second flight occurs, after which the beetles reënter the soil and hibernate. The average length of the life cycle of the 24 specimens was 92.6 days. The minimum period was 82 days and the maximum 119 days. The life cycle computed from the length of the different stages of development is shown in Table CIX. This average is 92.9 days, which is surprisingly close to the average of 92.6 days for the 34 reared beetles. The computed maximum life cycle deviates four days only, and the minimum eight days only from that observed in rearings.

TABLE CIX.—The computed life cycle of *Euphoria sepulchralis.*

STAGE.	Number of individuals.	Number of days.		
		Maximum.	Minimum.	Average.
Egg	27	13	9	11.8
Larva	25	87	56	65.7
Pupa	30	23	9	15.4
Life cycle		123	74	92.9

Summary of the Cetoniinæ

The life cycle of the species of this subfamily here discussed occupies one year. As noted previously, *Cotinus nitida* requires one year, and the evidence is strongly in favor of the same period for *Euphoria inda.*

The two species, *Euphoria fulgida* and *Euphoria sepulchralis,* differ in the manner of passing the winter, in that the former was observed to hibernate as a fully grown larva in the prepupal stage, while the latter passes the winter as an adult.

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ILLUSTRATIONS.

PLATES I TO X.

PLATE I.—Adult beetles: (1) *Phyllophaga fusca* Froelich. (2) *Phyllophaga vehemens* Horn. (3) *Phyllophaga tristis* Fabricius. (4) *Pelidnota punctata* Linnæus.

PLATE II.—Adult beetles: (1) *Cotalpa lanigera* Linnæus. (2) *Ligyrodes relictus* Say. (3) *Euphoria fulgida* Fabricius. (4) *Euphoria sepulchralis* Fabricius.

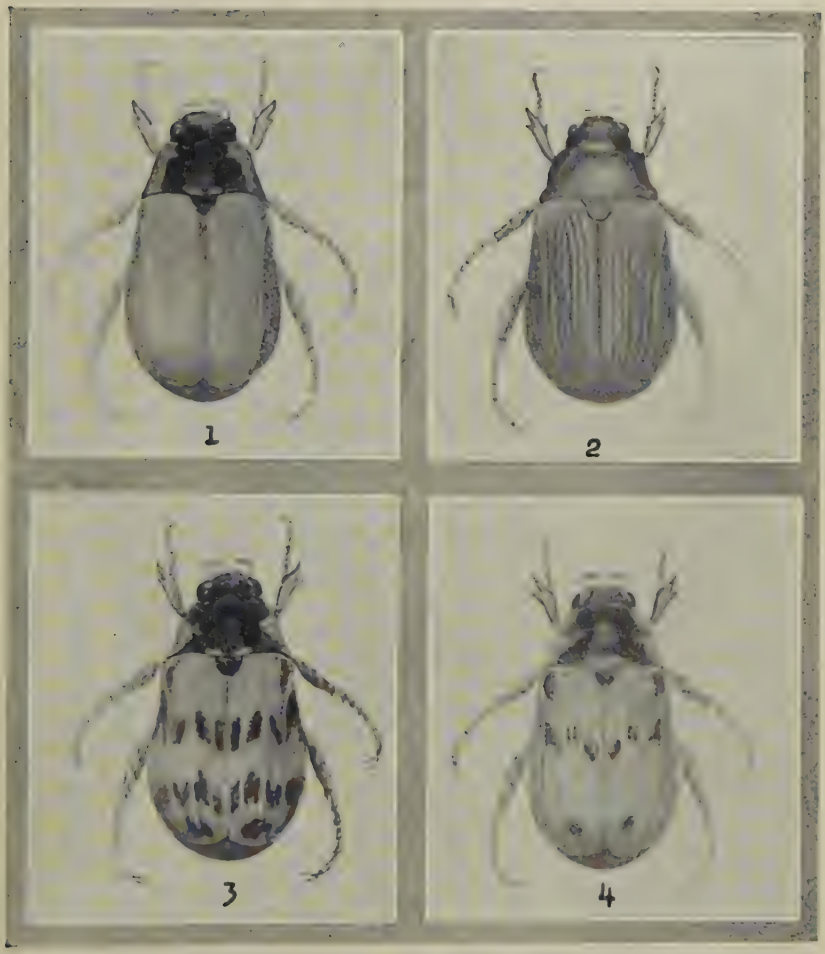


PLATE III.—Color varieties of *Anomala innubia* Fabricius: (1) With yellowish elytra. (2) With black elytra. (3) With spotted elytra. (4) With less spotted elytra.

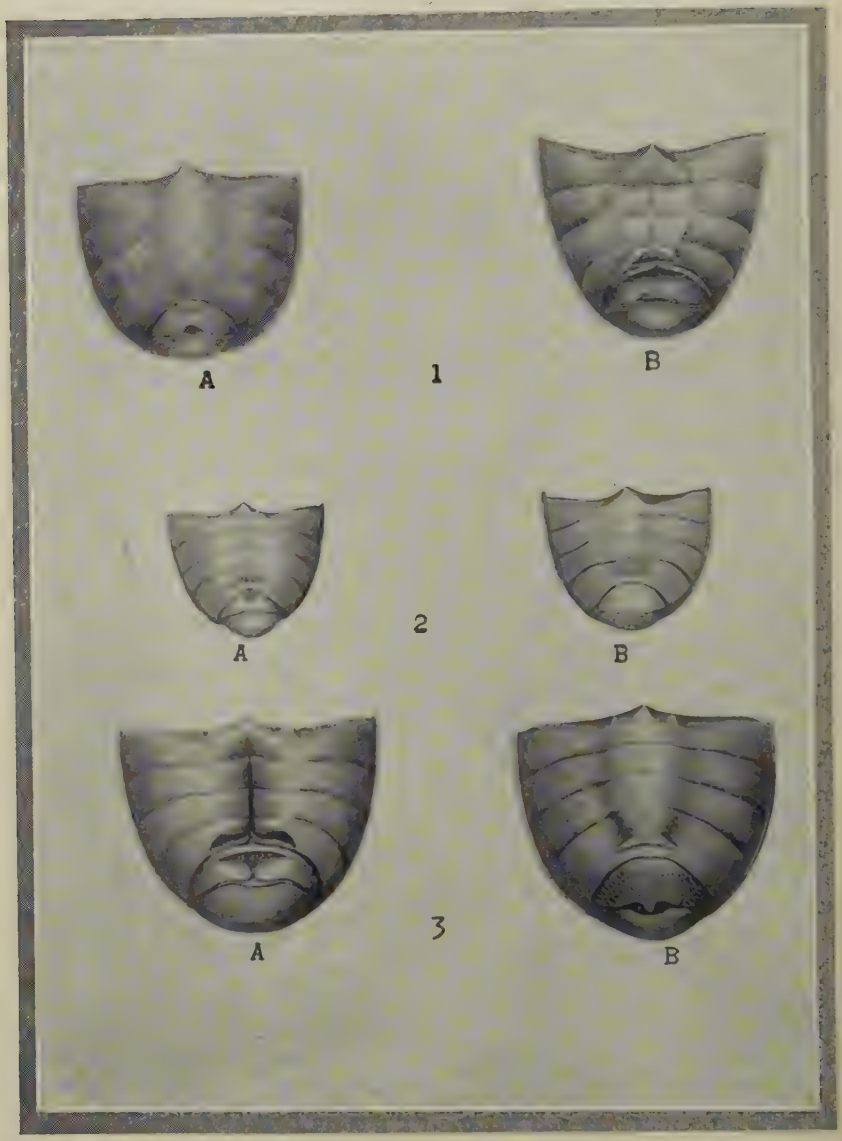


PLATE IV.—Ventral abdominal segments of the adult beetles showing sexual differences: (1) *Phyllophaga prætermissa*—(A) female, (B) male. (2) *Phyllophaga longitarsa*—(A) male, (B) female. (3) *Phyllophaga bipartita*—(A) male, (B) female.

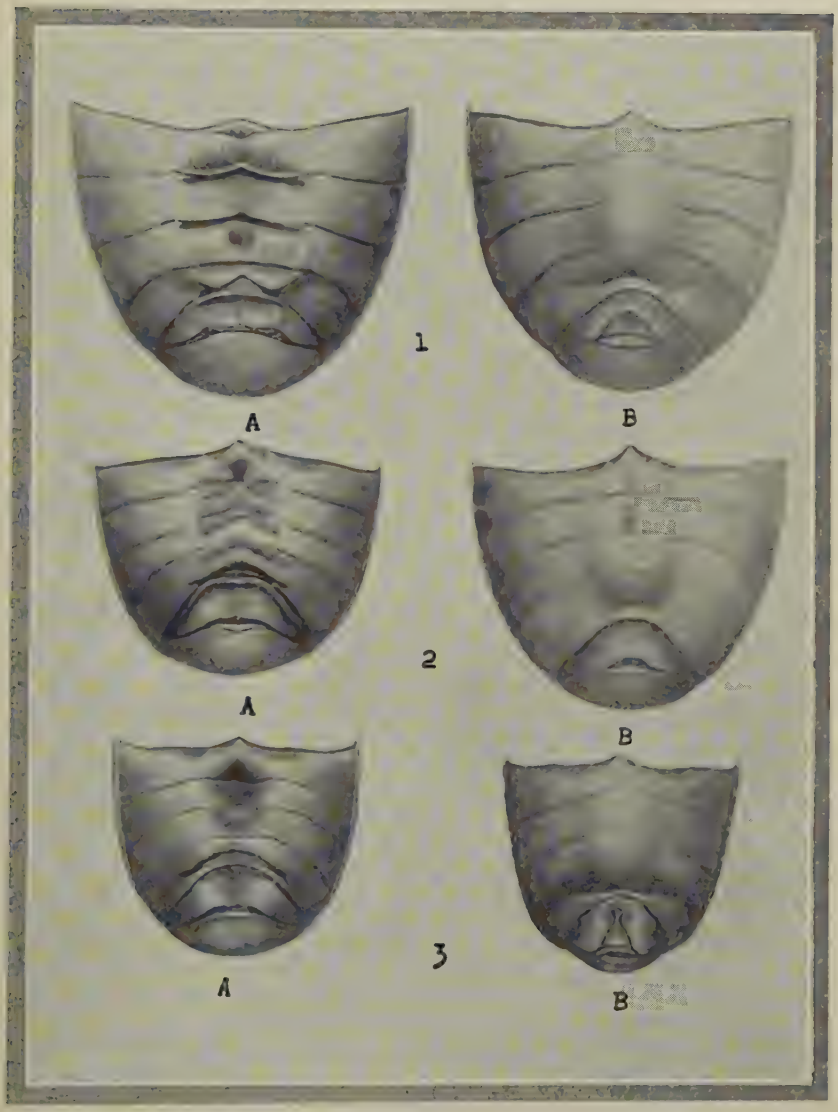


PLATE V.—Ventral abdominal segments of adult beetles showing sexual differences: (1) *Phyllophaga fusca*—(A) male, (B) female. (2) *Phyllophaga vehemens*—(A) male, (B) female. (3) *Phyllophaga corrosa*—(A) male, (B) female.

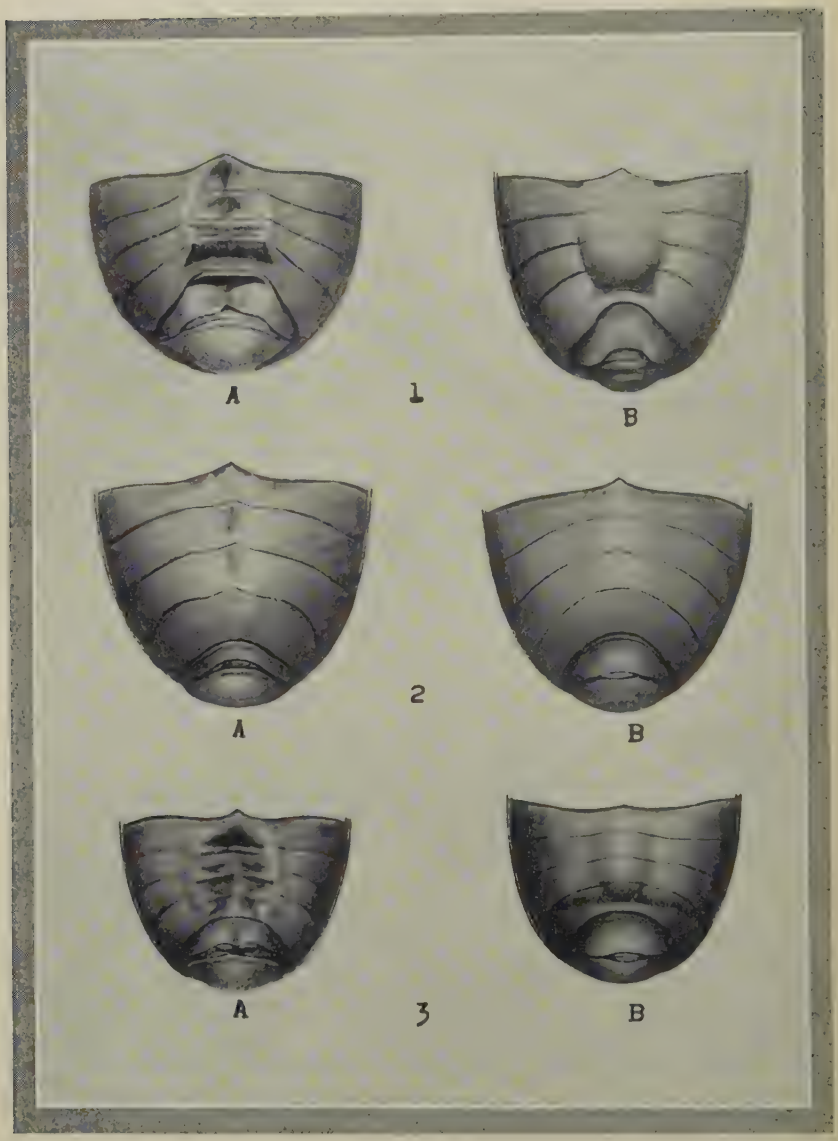


PLATE VI.—Ventral abdominal segments of adult beetles showing sexual differences: (1) *Phyllophaga hirticula* var. *comosa*—(A) male, (B) female. (2) *Phyllophaga crenulata*—(A) male, (B) female. (3) *Phyllophaga affabilis*—(A) male, (B) female.

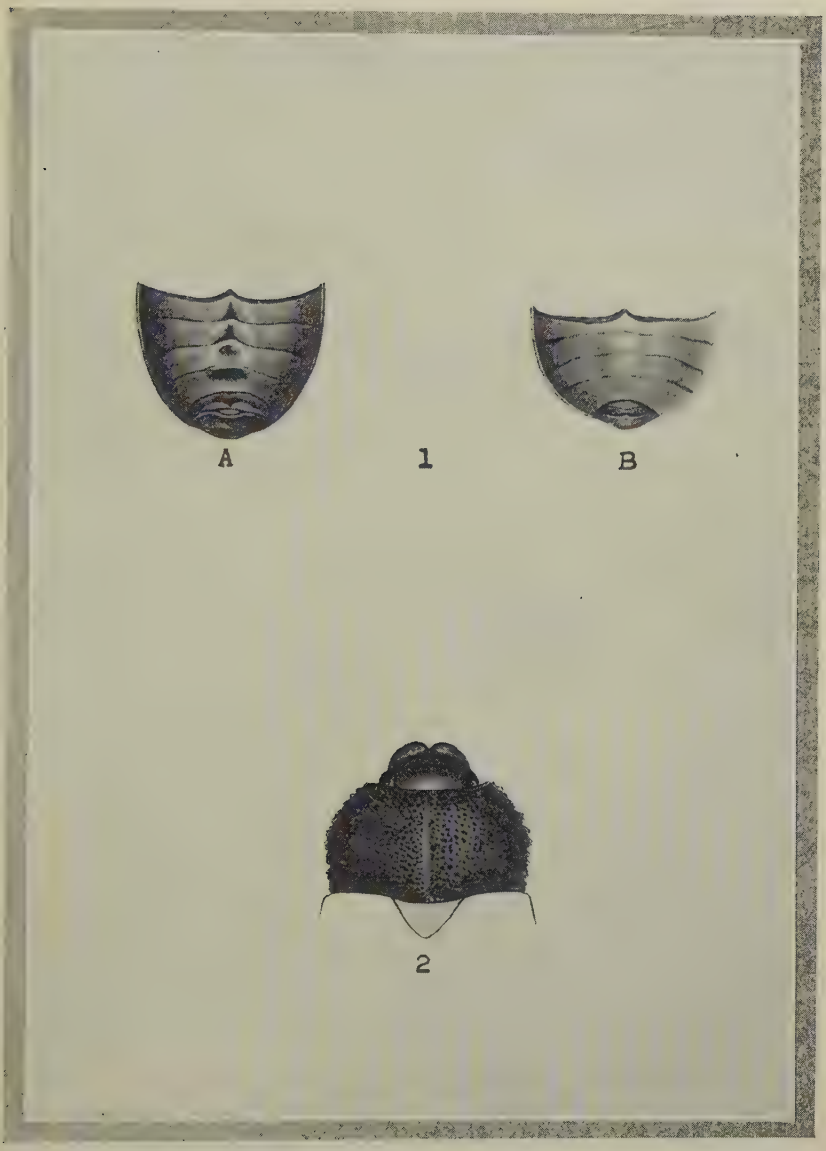


PLATE VII.—(1) Ventral abdominal segments of adult beetles of *Phyllophaga tristis* showing sexual differences—(A) male, (B) female. (2) Head and thorax of *Phyllophaga crenulata* showing the crenulation of the thorax.

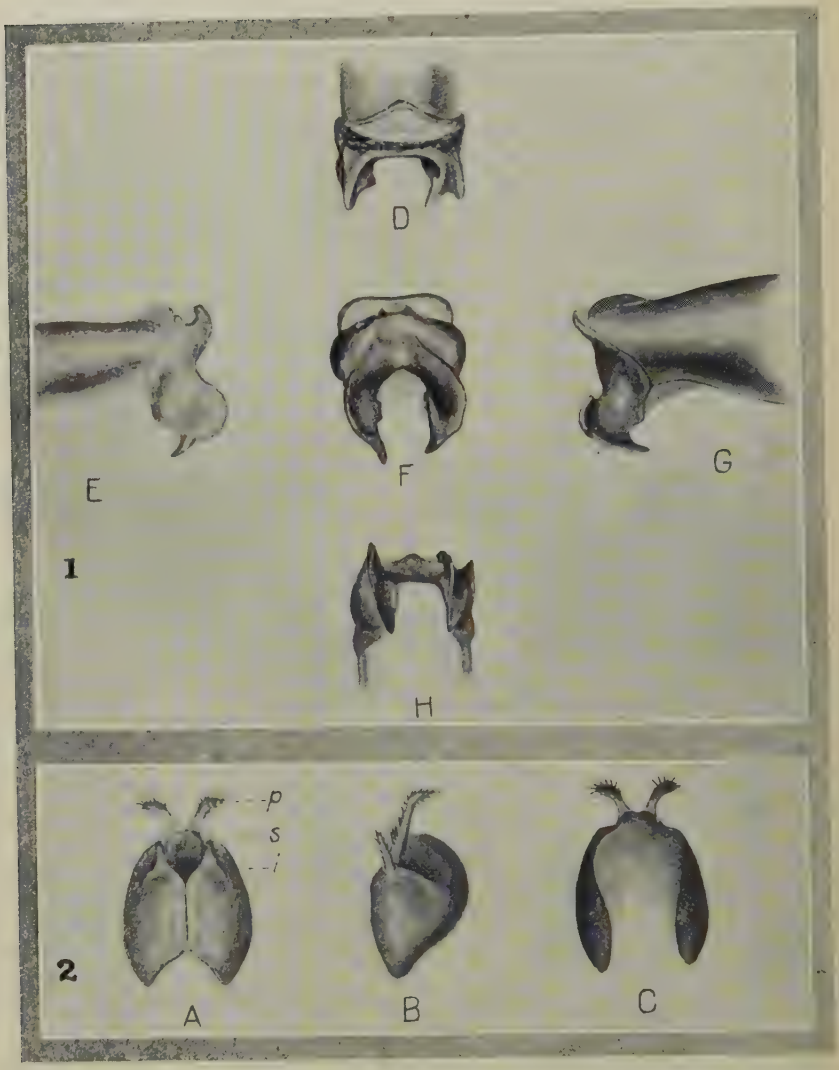


PLATE VIII.—The genitalia of *Phyllophaga corrosa:* (1) Male—(D) dorsal aspect, (E) left lateral aspect, (F) caudal aspect, (G) right aspect, (H) ventral aspect. (2) Female—(A) ventral aspect, (B) lateral aspect, (C) dorsal aspect.

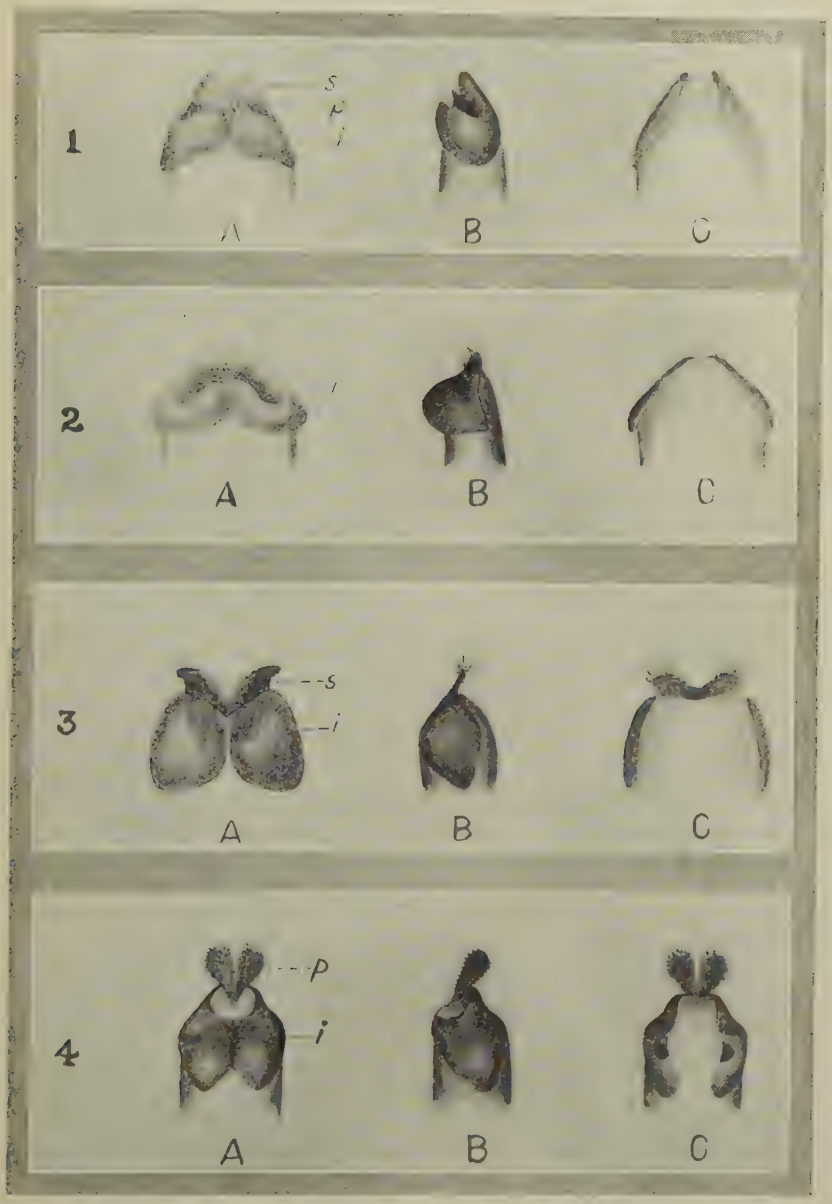
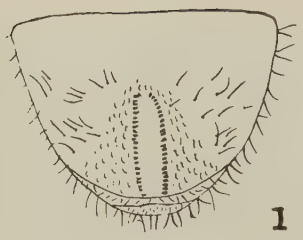
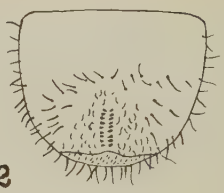
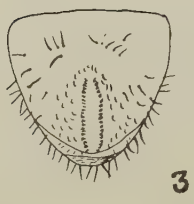
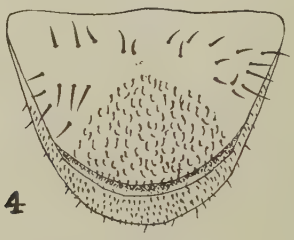


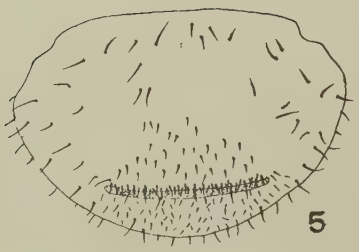
PLATE IX.—Female genitalia of *Phyllophaga* spp.: (1) *Phyllophaga longitarsa.* (2) *Phyllophaga tristis.* (3) *Phyllophaga crenulata.* (4) *Phyllophaga prætermissa.* (A) Ventral aspect, (B) lateral aspect, (C) dorsal aspect.

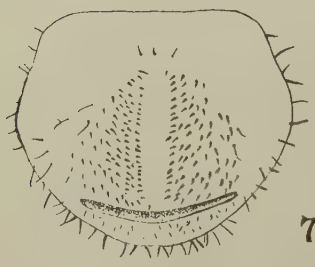












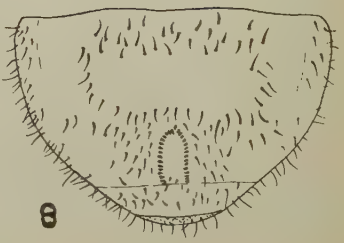


Plate X.—Ventral abdominal segments of larvæ: (1) *Phyllophaga hirticula* var. *comosa* Davis. (2) *Phyllophaga longitarsa* Say. (3) *Phyllophaga tristis* Fabricius. (4) *Cotalpa lanigera* Linnæus. (5) *Pelidnota punctata* Linnæus. (6) *Anomala innubia* Fabricius. (7) *Ligyrodes relictus* Say. (8) *Euphoria sepulchralis* Fabricius.

□

64 45 75 87 72
11 5 5 13 3
225 375 261 216
64 87
64 131
706
220
225
34
375
2060 upstairs
1131
216
3407